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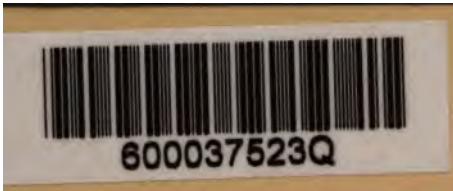
The Chemistry of Foods

BY

JAMES BELL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SCIENCE HANDBOOKS.

BRANCH MUSEUM, BETHNAL GREEN.

THE CHEMISTRY OF FOODS.

WITH MICROSCOPIC ILLUSTRATIONS.

BY

JAMES BELL, PH.D., &c.,

Principal of the Somerset House Laboratory, Member of the Council of the Institute of Chemistry, etc.

Part II.

MILK, BUTTER, CHEESE, CEREAL FOODS, PREPARED STARCHES, ETC.

Published for the Committee of Council on Education

BY

CHAPMAN AND HALL, LIMITED,

11, HENRIETTA STREET, COVENT GARDEN.

1883.

HORNIMAN'S PURE TEA IS THE BEST.

HOME is Woman's own kingdom. To rule in her husband's heart and home is, or ought to be, every wife's desire. If she can succeed in making his home happy, she need not fear losing her husband's heart; and in her own domain the mistress of a well regulated home realises the idea pictured in the lines of the poet Montgomery:

> Here woman reigns; the mother, daughter, wife,
> Strews with fresh flowers the narrow way of life.

England's happy homes have long been her greatest glory; and this is sufficient to prove that her merry maids make true wives and good mothers. Of course all husbands are not what they should be, and it would not be fair to give the wives the blame for all the misery that exists in many households. But certain it is that if both did their best there need be few uncomfortable homes; for modern life, with all its drawbacks, has given us many things to be thankful for. Every land under the sun is ransacked to provide the good things of life for Englishmen and Englishwomen, and there is no other country in which the women have such chances of making a pleasant, happy home. Even in the homes of the working men of to-day there are luxuries and pleasant things that kings and nobles might formerly have sighed for in vain.

Take that simple article, TEA, which has given its name to the pleasantest family meal of the day. Not so very long ago tea was such a luxury, that a *two pound* packet was considered a present worthy of an English king! To-day, hundreds of ships, thousands of men, and millions of money are annually employed in order that the families of England may have a supply of tea, in the consumption of which we rival the Chinese themselves; all praise, then, is due to so superior a beverage that cheers, refreshes, stimulates, and gives such universal enjoyment and delight! *But what is* TEA? *that is the question.* Real Tea, yielding an exquisite aroma, delicious flavour, and amazing strength in the cup, is produced by infusing the first crop leaf of early Spring (April). This gathering commences just as the bud begins to unfold, and when the shrub is full of succulent sap and rich juices. The preparation is simple; the rolling and drying of the leaves is a process easily applied, and intended to expel all moisture, but at the same time retain all the aromatic and valuable properties of the leaf. The firing is done in iron pans, which are round and shallow, and kept to an even heat by aid of a charcoal fire. It is an interesting sight in the season to view the busy workers carefully preparing tea for the market. Of course our remarks apply to PURE TEA, of the early Spring growth only; there are many later gatherings of the Autumn crop, when the leaf is old and tough, instead of young and tender; and this description would be quite unsalable but for the system of adulteration commonly practised to make the brown withered leaf *appear* equal to fine tea. That well-known and earnest traveller, the late Mr. Robert Fortune, thus describes the process of producing that "beautiful bloom," which is pretty to the eye, but deadly to the taste: "There is now no doubt that all these faced teas are dyed with Prussian blue and gypsum, or plumbago, to suit the taste of the foreign 'barbarians.' The process may be seen any day, by those who give themselves the trouble to seek after it. Black teas are coated with gypsum to give weight and a sticky nature to the leaf, plumbago and lampblack to cover the white of the gypsum, and ferruginous earth to deepen the red of the liquor. The Chinese never use these dyed teas themselves." (See Fortune's work—*How China Tea is elaborated for the European Market.*)

Some forty years ago the well-known firm of HORNIMAN & Co. determined to supply a great want of the public. The strong desire evinced for tea without the usual mineral facing powder induced MESSRS. HORNIMAN to send orders to China for PURE TEA—and as the Chinese themselves drink it. The large shipments of this firm found a ready sale amongst all classes of tea-drinkers, it being at once apparent that the tea "without paint" was infinitely superior in aroma, as well as exceedingly strong and delicious to the taste; from that time the demand for HORNIMAN'S PURE TEA has been daily increasing; their specialité is sold in every City, Town, and Village in the Kingdom by four thousand Chemists, who are authorised Agents; the annual sale now exceeds six million packets; and Agencies are extended to all the principal Cities of France, Germany, Russia, Italy, Austria, Belgium, Switzerland, Holland, Norway, Sweden, Denmark, etc. etc.

For the guidance of purchasers, HORNIMAN'S TEA has the following distinctive characters:

Each packet bears the signature W. H. & F. J. HORNIMAN & Co., London, Original Importers of the PURE TEA. Each tinfoil and paper wrapper has the price plainly printed thereon to prevent mistakes. Each label gives a description of the contents—whether BLACK TEA, GREEN TEA, or MIXED TEA. The BLACK is warranted free from plumbago or any other mineral facing powder; the GREEN TEA is free from Prussian blue, gypsum, or any deleterious compound whatever. Long experience has shown beyond any question of doubt that the system of packing by machinery—peculiar to MESSRS. HORNIMAN—is the best for protecting the TEA, and preserving its aroma and flavour. TEA is got up for sale put into bottles, tins, and other costly inventions; but MESSRS. HORNIMAN are enabled to give better value TEA by *not* adopting a costly and useless exterior covering.

Finally, HORNIMAN'S TEAS are supplied by Chemists in the Country, and Confectioners in London. A list of local names is printed in your district Newspapers, and at the Railway Stations.

***HORNIMAN'S* PACKET TEA HAS FOR 40 YEARS BEEN SUPPLIED BY *AGENTS*, CHEMISTS, AND CONFECTIONERS.**

SOUTH KENSINGTON MUSEUM SCIENCE HANDBOOKS.

[BRANCH MUSEUM, BETHNAL GREEN.]

THE CHEMISTRY OF FOODS.—PART II.

CONTENTS OF PART I.

TEA.

COFFEE.

COCOA.

SUGAR.

HONEY.

THE

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WITH MICROSCOPIC ILLUSTRATIONS.

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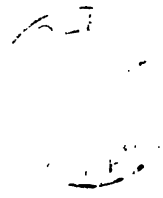

PREFACE.

THE same plan of arrangement has been followed in the present as in Part I.

Each article has been made the subject of a special investigation, and much of the chemical matter is new, and the whole of the analytical results are original.

The researches on milk include an investigation into the variations which occur in its composition, and it is to be hoped that the results of this part of the inquiry will serve to settle the vexed question as to the alleged constancy in the composition of cow's milk, especially in the non-fatty solids. The samples were obtained from different parts of the country, and comprise milk yielded both by house and grass fed cows, and every effort was made to obtain fair representative specimens of milk yielded by different cows, and under the ordinary conditions of changes of food and season.

A reliable process for the analysis of sour milk has appeared for some time to be a want which it was desirable to supply. The method described is based on a carefully conducted series of experiments, and the process has been found to give accurate results.

Besides cow's milk, samples of several other kinds have been procured, and their proximate constituents, which are given, may prove interesting, if not useful, for comparison.

The further experiments on butter-fat have confirmed the theory which was indicated by me in Parliamentary Paper No. 293 (June, 1876), that the radicals of the soluble and

insoluble fatty acids are combined with glycerin in the same molecule to form a compound ethereal salt.

In anticipation of the introduction into this country of lard and oleomargarine cheeses, it was deemed desirable to deal with the subject, and show wherein they differ from pure milk cheese.

Several interesting results have been observed during the course of the study of the cereal foods. The saccharine matter which occurs in bread, made both by the aërated and fermentative methods, has been identified as maltose. Contrary to the views sometimes put forward by the advocates of the use of wheat-meal bread, the samples of household flour submitted to analysis were found richer in nitrogenous matter than the entire wheat grain. The soluble albuminoids of the cereals have been found to possess the diastatic action on starch in varying degrees, the converting power of those of rye possessing this property in a pre-eminent degree.

Arrowroot, sago, tapioca, and corn flour have been classed under the general head of Prepared Starches, as being the most appropriate term to designate their character as foods; for, as is mentioned under the head of corn flour, their value in this respect is still over-estimated by the general public.

I have pleasure in recording my obligations to the analysts of the department for the able and cheerful assistance which they have rendered me in the preparation of both the first and the present Parts of this work.

JAMES BELL.

LABORATORY DEPARTMENT,
SOMERSET HOUSE,
March, 1883.

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PART II

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MILK.

Origin.—Milk is the fluid secreted by all female mammals for the nourishment of their young, and hence has come to be considered the *model* food.

The distinctive characters which milk possesses are believed to be imparted to it during its passage through the mammary glands; but no satisfactory explanation has been given as to how the milk-sugar is formed, or how the fibrin and albumin of the blood become changed, physically if not chemically, into milk casein and albumin; or as to the process by which the insertion of a new kind of acid radical in the ordinary fatty molecule has been brought about.

Milk, as a source of nourishment, is perhaps more allied to an animal than to a vegetable food. If, however, in considering all its constituents, we regard milk-sugar as replacing some of the starchy matter of cereals, we have in milk an alimentary substance, taking an intermediate position between the cereal and the strictly animal foods, and having its composition so admirably adjusted, that it may be regarded as a perfect food.

Description.—The following remarks have special reference to the milk obtained from the cow, but the description is generally applicable to human milk and that of the ewe, goat, and mare. It will be seen from the results of the analyses in Tables I. and III. that the same constituents are present in all of these milks, though differing considerably in the proportions in which they occur in each kind.

Milk is an opaque fluid, generally of a white or yellowish white colour, having a specific gravity varying from about 1027° to 1035°.

The colour is due essentially to the presence of suspended fatty globules; for, on allowing milk to stand for some time until the cream rises to the surface, the appearance of the body of liquid below is less opaque than the fresh milk.

The taste of fresh milk is somewhat sweet, and it has a slight but characteristic odour.

The appearance of milk is not so subject as its quality to variations on account of breed, age, changes in health, food or general condition of the animal yielding it. The most noticeable change is during the first three or four days after parturition. The milk of the cow is then of a rich yellow colour, has a higher specific gravity, and, from the larger proportion of albumin which it contains, coagulates more readily than ordinary milk. During this period it is called *colostrum.*

History.—The milk of animals has been used and valued as an article of food from the earliest ages. At a very early period, to speak of a "land flowing with milk and honey" was regarded as synonymous with plenty, and from the many allusions to milk, which included that of the ewe and goat, it is obvious that it must have formed an important part in the dietary of the earlier nations.

Hippocrates, the celebrated physician of the old world, prescribed milk—either that of the cow, ewe, or goat—in certain ailments, but forbade its use in cases of headache, fever, and bilious attacks. Amongst the Romans, bread soaked in asses' milk was rubbed over the body to make the skin fairer.

Asses' milk was prescribed by a celebrated Jewish doctor, summoned from Constantinople, to attend Francis I. of France, when suffering from a wasting and debilitating illness, and the remedy having proved successful in the monarch's case, its use became fashionable with the court.

Anything like an accurate knowledge of the chemistry of milk was unknown before the close of the eighteenth century. *There was* indeed a very early acquaintance with butter, curd,

and whey; but this information remained for many centuries nearly all that was known regarding it.

It is only during comparatively recent years that the composition and properties of the several characteristic substances found in milk have been fully investigated, and their proportions in the various kinds of milks accurately estimated.

CHEMICAL COMPOSITION.

When milk is allowed to stand for some time the cream rises to the surface. If this be removed, the remaining liquid will after a further period spontaneously separate into a solid portion called *curd*, and a liquid called *whey* or *serum*, which is essentially an aqueous solution of milk-sugar. By a sort of natural analysis we thus find that milk is divisible into *Cream*, *Curd*, and a watery solution of milk-sugar with a little mineral matter.

The following table contains the results of the analyses of five samples of milk:

TABLE I.—CONSTITUENTS OF COW'S MILK.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Specific Gravity ...	1031·56	1031·56	1031·00	1032·50	1029·80
Total Solids	11·47	11·09	11·98	12·79	15·89
Non-fatty Solids ...	8·71	8·66	8·65	9·03	9·10
Fatty percentage ...	2·76	2·43	3·33	3·76	6·79
Casein ,, ...	3·05	2·96	3·18	3·50	3·31
Sugar ,, ...	4·91	4·96	4·75	4·75	5·07
Ash ,, ...	0·75	0·74	0·72	0·78	0·72
Water ,, ...	88·53	88·91	88·02	87·21	84·11
Total	100·00	100·00	100·00	100·00	100·00

Fat.—This, in a somewhat impure state, owing to the presence of curd and milk-sugar, constitutes butter. Whilst present in the milk the fat exists in the form of globules suspended in the liquid. It has been debated whether these globules have an envelope or

not, but we do not think there is proof of the existence of any covering beyond that which might arise from the slightly adherent portion of the non-fatty liquid in which they are suspended.

As the fat globules at ordinary temperatures are in a solid condition—that is, as solid as butter fat at the same temperature—it can easily be understood how a portion of the milk fluid would adhere to the exterior surface of the fat particles. If this view is correct the production of butter is explained, not by the fusion of oily globules liberated from an envelope, but by the cohesion of solid particles of fat brought into contact by the agitation of the milk during the operation of churning, for the distinctly globular condition of the fat is maintained in the aggregated fat at the end of the process.

Casein or *Curd.*—This consists of albuminous substances mixed with a small proportion of mineral matter. The former are divided into at least two kinds of nitrogenous bodies called respectively casein and albumin. The casein is precipitated by acetic and other acids as a curdy mass. This does not hold good of the nitrogenous matters present in the milk of all the mammals, as in some milks these substances are only very imperfectly separated by the addition of an acid.

It is probable that in the different milks we have something of the same variety of physical character in the casein that we find in the nitrogenous substances present in the several cereals.

The soluble casein or albumin is coagulated by heat, and may be separated by filtration. In its characters it closely resembles ordinary albumin.

Milk-sugar, $C_{12}H_{22}O_{11}$.—This is an important and characteristic constituent of milk, and, as before stated, forms the chief substance in solution in the whey or serum.

As milk-sugar appears to be the ingredient of most constant proportion in milk, the variations in the specific gravity of the serum in genuine milk fall within much narrower limits than in *milk itself.*

If the serum, after separation of the curd has been effected by addition of rennet, be evaporated on the water-bath, we obtain more or less perfect crystals of a sweet taste. These, purified by animal charcoal and recrystallized, finally appear as hard, semi-transparent, white, hemihedral, trimetric crystals, having the same formula as cane-sugar, and nearly the same specific gravity, viz. 1·52. The crystals are soluble in water, but insoluble in absolute alcohol and ether.

Milk-sugar approximates to dextrose in its action on polarized light, having a rotatory angle of 59·3° [*a.*] j., and is converted by boiling with sulphuric acid into dextrose and galactose. The latter crystallizes in prisms, and its copper-reducing power is one-fifth less than that of dextrose.

Ash.—The ash or mineral matter obtained by careful incineration of fresh milk amounts to from about ·62 to ·87 per cent., and contains chlorides of sodium and potassium, phosphates of calcium, magnesium, and potassium, with a small quantity of sulphates, and traces of carbonates.

The following table exhibits the composition of the ash of four samples of cow's milk :

TABLE II.—CONSTITUENTS OF THE ASH OF COW'S MILK.

Percentage of		Average Milk of 29 Cows.	Average Milk of several Cows.	Average Milk of several Cows.	Milk of Shorthorn 5 years old.
Total Ash		0·73	0·72	0·78	0·71
Potash—estimated as ...	K_2O	17·24	19·53	19·78	19·83
Soda ,, ,, ...	Na_2O	4·29	3·30	3·67	3·19
Lime ,, ,, ...	CaO	24·53	24·48	24·78	25·98
Magnesia ,, ,, ...	MgO	2·89	4·76	4·35	3·68
Phosphoric Anhydride...	P_2O_5	35·67	32·49	32·07	32·67
Sulphuric ,, ...	SO_3	2·65	0·92	0·69	1·62
Chlorine	Cl	12·73	14·52	14·66	13·03
Total		100·00	100·00	100·00	100·00

Composition of other Milks.

The milks of the cow, goat, mare, and other mammals, though having a general resemblance in composition, differ considerably from each other in regard to the relative proportions which the constituents bear to each other, and also, in some degree, in the character of the constituents themselves.

The following table contains the results of the analyses of four kinds of milk :

Table III.—Analyses of Different Kinds of Milk.

Constituents.	Woman age 18.	Woman age 33.	Mare.	Goat.	Ewe.
Specific Gravity ...	1034·50	1033·03	1036·12	1032·70	1039·30
Fat	3·20	2·99	1·76	5·80	11·28
Casein, Albumin, etc.	2·39	2·51	3·58	4·20	8·83
Sugar	6·83	6·51	5·87	4·94	3·58
Ash	·29	·30	·39	1·00	1·09
Water...	87·29	87·69	88·40	84·06	75·22
Total	100·00	100·00	100·00	100·00	100·00

In the milk of the cow and goat the proportion of casein and albuminous matter is nearly equal to that of the sugar, but in woman's milk the sugar is considerably in excess of the casein. The same generally holds good of mare's milk, though great variations in the quantity of milk-sugar have been found. Under high feeding the sugar is decreased, but when the animal is kept at grass of a poor quality, the sugar is found in much greater quantity than the casein. The casein of the milk of the mare possesses physical properties which distinguish it from that of the milk of the cow or goat. On the addition of acetic acid, the casein appears in a suspended or apparently soluble condition, a property also common to the casein of woman's milk in nearly the same degree, and this has led some to ascribe to it a rather

different constitution to that of the casein of cow's milk, and to regard such milk as more digestible and more easily assimilated by infants and weakly persons.

The fat obtained from the milk of different mammals is distinguished from other animal and vegetable fats by containing a larger proportion of the glycerides of the soluble fatty acids. The percentage of these acids yielded by the fat of cow's, goat's, and ewe's milk is nearly identical. Mare's milk yields an oily fat very rich in soluble acids, among which butyric is not so apparent as in the fat of cow's milk.

Koumiss.—Mare's milk is extensively used as an article of food in a partly fermented condition under the name of *koumiss*, by many of the tribes inhabiting the steppes of Russia. It appears to lend itself with greater facility than the milk of other mammals for preparations of this kind, owing no doubt to the soluble character of its albumin, and the relatively large proportion of milk-sugar contained in it when the animals are kept in a nearly wild condition.

The milk, on being drawn, is set aside for some time and deprived of part of its cream, after which the addition of a little yeast, or artificial ferment, sets up a slow fermentation, the sugar being thereby converted into alcohol and lactic acid. During fermentation, the milk is subjected to frequent agitation, the object apparently being to retain in suspension the casein, part of which has a tendency to separate on the milk becoming sour.

The following results of an analysis of Russian koumiss will give an idea of the composition of a preparation of this kind:

Acid, as Lactic	1·96
Casein	2·11
Sugar	0·40
Fat	1·10
Alcohol	2·12
Ash	0·34
Water	91·97
Total	100·00

The following table contains the results of the analyses of the ash of four kinds of milk:

TABLE IV.—COMPOSITION OF THE ASH OF VARIOUS MILKS.

Constituents.	Woman.	Goat.	Mare.	Ewe.
Total Ash per cent.... ...	0·29	1·00	0·39	1·09
Potash ... ... K_2O	30·80	16·98	16·35	11·42
Soda ... ... Na_2O	3·26	2·67	2·77	1·56
Lime ... ... CaO	18·47	25·69	35·19	36·32
Magnesia ... ... MgO	3·98	4·57	3·40	4·68
Phosphoric Anhydride... P_2O_5	23·93	42·28	32·73	38·99
Sulphuric ,, ... SO_3	7·97	2·23	3·08	3·32
Chlorine Cl	11·59	5·58	6·48	3·71
Total	100·00	100·00	100·00	100·00

ANALYSIS.

Specific Gravity.—The specific gravity of milk, though not by any means a conclusive test of its quality, yet, when taken in conjunction with the amount of cream, supplies a rough guide to those who have no facility nor appliances for conducting an exact chemical analysis. The gravity may be taken with an ordinary weighing bottle, or with a lactometer, which is more commonly used, with a scale on the stem, indicating degrees of gravity above that of water (1000). As the instruments are usually adjusted at 60° F. (15·5° C.), a correction requires to be made for temperature to the extent of nearly one degree in specific gravity for every ten degrees of temperature above or below 60° F. Thus, if a milk had an apparent specific gravity of 1030° at 70° F. (21·1° C.), the corrected gravity at the standard temperature would be about 1031°. As cream is lighter than the rest of the milk its abstraction raises the specific gravity of the milk, and for the same reason the presence of a large proportion of cream

lowers the gravity. A low gravity, therefore, may indicate a milk rich in fat, or one to which water has been added; and if the quantity of cream which separated from milk always bore a fixed relation to the percentage of fat in it, the determination of the gravity of the milk and the proportion of cream would furnish sufficient data for ascertaining the quality of a milk for ordinary purposes. We have found, however, that the proportion of cream which separates from milk is often very far from indicating the true amount of fat. The results of some experiments gave, on the average, three parts of separated cream for every part of fat actually present, but the proportion of cream was often in the relation of 1½ to 1 of fat, and sometimes it was 4 or 5 times the proportion of fat obtained. The specific gravity, even in conjunction with the percentage of cream, affords, therefore, only a rough indication as to whether water has been added to milk or not.

Total Solids.—The determination of the total solid matter in fresh milk is a comparatively easy operation. Five grams of the milk are weighed in an accurately tared platinum capsule, which is placed on an aperture of a water-bath and at the end of about three hours, or less, when the residue is sufficiently dry, the capsule is removed to a water-oven to complete the drying. The capsule is afterwards weighed at intervals till a constant weight is obtained. It is important that the bottom of the capsule should be flat, or nearly so, and that the size should be such that, after the whole of the water has evaporated, the dry residue will be left in the form of a thin film.

It has sometimes been recommended, in order to facilitate perfect drying, that a known quantity of sand or pulverized glass should be added to the milk in the capsule; but this, according to our experience, is unnecessary, if care is taken to employ a capsule of the description mentioned.

Non-fatty Solids and Fat.—When the milk is fresh, a quantity

of exactly 10 grams may be weighed in a platinum capsule containing a glass stirrer. The most suitable size of the capsule for this purpose is one having a diameter of 3 inches and a depth of 1 inch. The capsule is placed on an aperture of a water bath, and its contents evaporated almost to dryness. It is of advantage to keep the milk well stirred during the process of drying, in order to insure that the solid residue be obtained in a condition favourable for the complete extraction of the fat. The milk residue should neither be too moist nor too dry, as either condition tends to prevent the removal of the last traces of fat. If the evaporation has been carried too far, the residue may be carefully moistened either with a very small quantity of water, or of alcohol. When the proper point has been reached, the mass is treated repeatedly with ether, the stirrer being each time used to pulverize the solid matter which, in order to insure that no portion escapes the action of the solvent, should assume a fine state of division. The ether is used warm for the last three treatments. After each washing the ethereal solution of the fat is carefully poured off through a small Swedish filter not exceeding 3½ inches in diameter. To remove the last traces of fat from the filter, the upper part is cut off, divided into small pieces, which are placed in the remaining portion of the filter in the funnel, and washed with a little ether. The filtrates are received into a tared beaker from which the ether is gently evaporated, and the fatty residue finally dried in a water-oven until the weight is constant.

The capsule containing the non-fatty residue is placed on the open water-bath for two hours, and subsequently for two or more hours in a closed water-oven kept at 212° F. (100° C.), until a constant weight is arrived at. This result should be obtained in the time stated if the milk solids have been finely pulverized in the process of fat extraction.

The determination of the fat, non-fatty solids, and ash, should be made in duplicate; and, as a further check on the analysis, the

total amount of milk solids may be ascertained in a third portion of the milk, which may afterwards be used for one of the determinations of the ash. It ought to be observed that, for some reason, probably connected in some way with the presence of fat, the final weighing of the total solids is seldom, if ever, so satisfactory as that of the non-fatty solids. In no case, therefore, would we advise that the non-fatty solids should be determined by deducting the weight of fat actually obtained from that of the total solids.

We have experimented with Soxhlet's apparatus and similar appliances for extracting the fat by simple contact with the solvent used; but they have failed to yield as satisfactory results as those which we have obtained by the maceration process above described. We have usually obtained from ·3 to ·5 per cent. more fat by the latter method than by means of Soxhlet's apparatus. Though on this account not suitable where great accuracy is demanded, the contrivance affords many facilities for the extraction of fat from such substances as ground seeds and cereals, in which a fine state of division is easily attainable. The process may also be conveniently adopted in cases of milk analysis where very exact results are not required.

An indirect method of arriving at the percentages of fat and non-fatty solids was suggested by Mayer and Clausnitzer, and recently a modification of their formula for calculating the results has been proposed by O. Hehner. The method is based on the accurate determination of the specific gravity and total solids of the milk, and the application to these of certain experimental data derived from the specific gravity of the fat and non-fatty solids. The theoretical results, however, which are calculated from even the modified formula proposed by Hehner, are in most instances too high in the non-fatty solids, and to the same extent too low in the fat; but the amounts are sufficiently near accuracy, especially in the case of samples of average quality, to be useful where the adoption of a quick and ready method of milk analysis is a

desideratum. In cases, however, where unquestionable accuracy is required, the variations from the true percentages, as given by this method, are a fatal objection to its general use.

The mode in which the theoretical percentages of non-fatty solids and fat are arrived at from the specific gravity and total solids, is to multiply the total solids by the factor 0·725, add the product to the degrees of gravity, or the weight above 1000, and divide the same by 4·33, and the quotient will be the percentage of non-fatty solids. The difference between the total solids and non-fatty solids will be the percentage of fat.

Casein and Albumin.—The main nitrogenous constituents of milk obtained from a healthy mammal consist of what may be called casein and albumin. There also appear to be present comparatively small quantities of other substances containing nitrogen. In this respect milk agrees with many other complex natural products, in which also are found a certain proportion of undefined substances which may be regarded as bodies in different stages of progress towards the perfect condition of recognized principles. In estimating the casein it is usually sufficient to determine the total nitrogen in the dry residue of the milk, and calculate the whole as casein or albumin by multiplying the weight of nitrogen by 6·3. For the separation of the nitrogenous substances into casein and albumin, one or two methods, such as the following, have been proposed; but these can only be regarded as giving approximately correct results.

To a given weight of milk is added acetic or a dilute mineral acid until there is formed a distinct coagulum of casein, which is filtered, washed, and finally treated with ether to extract any fat carried down with the precipitate. The casein precipitate is then dried, weighed and ignited, and the mineral matter left deducted from the total weight of the casein.

The acid filtrate resulting from the separation of the casein is boiled for a short time, when a further precipitate of albuminous

matter is obtained, which may be washed and dried as above. Small quantities of other nitrogenous principles can be precipitated from the filtrate by the addition of mercurous-nitrate; but the quantity obtained is very small, and possesses little definite character.

Milk-sugar.—The quantity of milk-sugar is conveniently estimated by the polariscope: 50 cubic centimetres of milk are introduced into a 100 cubic centimetres flask, and a sufficient quantity of solution of basic acetate of lead added to give a bright filtrate. The whole is made up to 100 cubic centimetres with distilled water, and filtered. The angle of rotation is observed through a 200 mm. tube filled with the clear solution, and the percentage of sugar estimated by taking 59·3° as the specific rotation of milk-sugar.

The sugar may also be determined volumetrically or gravimetrically as previously described under "Sugar" (Part I. p. 106). It is necessary to remove the casein before proceeding to estimate the sugar. This may be done by a solution of acetate of lead or sulphate of copper. If the latter is used, a solution of potash of equivalent strength is added, when all, or nearly all, the copper will be precipitated.

The copper-reducing power of milk-sugar is 70·5, that of dextrose being 100; and hence the result obtained as dextrose will require to be converted into percentage of milk-sugar by mutiplying by $\frac{100}{70\cdot5}$.

Ash.—The non-fatty solids may be employed for the estimation of the total ash. The incineration should be conducted at as low a temperature as possible, using an Argand burner for the purpose. The ash should become perfectly white before the final weight is taken. It should not be allowed to fuse, nor should a Bunsen flame be employed, otherwise a loss of ash may occur. The ash residue is afterwards treated with distilled water, and the chlorine therein estimated volumetrically by a decinormal solution

of nitrate of silver. In a full analysis of the ash three quantities of from 50 to 100 grams are taken—one for alkalis, another for chlorides and sulphates, and the third for phosphates, all of which are separated and determined according to the usual methods.

Analysis of Skim Milk.

When milk has stood at rest from twenty to twenty-four hours the greater portion of the fat separates, and may be skimmed off. The remaining portion is called skim milk, but it still contains from 0·5 to 1 per cent. of fat, consisting of fatty globules much smaller in size than those forming the bulk of the cream. Their motion through the milk being slower than the larger globules, there is no possibility, from their want of sufficient buoyancy, of reaching the surface before it becomes necessary to remove the cream. Milk, after skimming, shows a rather higher percentage of non-fatty solids than before the cream was removed; which naturally arises from the relatively larger proportion of non-fatty fluid in skim milk. On this account it is only fair to judge of the genuineness of a skim-milk by a somewhat higher average limit than in the case of normal milk. The process of analysis differs, of course, in no respect from that adopted in the case of ordinary milk.

Analysis of Sour Milk.

It not unfrequently happens that an analysis has to be made of samples of milk which have been kept for some time —that is, for a period of from two or three days to about four weeks—during which time the milk has become sour and coagulated. In such cases a slight diminution in the non-fatty solids will have taken place, as the result of an incipient form of fermentation which changes a portion of the milk-sugar chiefly into lactic acid, and, to a smaller extent, into alcohol and carbonic acid gas. It is, no doubt, owing to the forma-

tion of a little alcohol that the depreciation of the non-fatty solids is due, as milk-sugar changes into lactic acid practically without any loss of weight; and as the acid is not volatile, its weight is correctly indicated on drying the milk. But the weight of the sugar decomposed by alcholic fermentation is almost entirely lost, as the alcohol disappears on evaporation, and only that small portion of carbonic acid gas which is held in solution in the milk is retained on neutralizing the milk as aftermentioned. It is evident, therefore, that some allowance should be made for decomposition in the way of addition to the amount of non-fatty solids, according to the time the milk has been kept, in order to obtain a correct estimate of the composition of the milk before any change had taken place.

It has been alleged that the fat in sour milk increases at the expense of the albuminous matter; but the results of our investigations show that the statement is without foundation. It is not unusual to obtain from sour milk about ·05 per cent. of fat more than from the same milk in the fresh state, but this arises partly from the fact that, owing to the diminution of the non-fatty solids, 100 parts of the decomposed milk represent rather more than 100 parts of the milk in its original state, and partly from the greater ease with which the residue from neutralized sour milk can be brought into a fine state of division, thus enabling the ether to act more effectively in dissolving out the last trace of fat.

In estimating the non-fatty solids and fat in sour milks, it becomes necessary to adopt a modification of the process given for the analysis of fresh milk, as the lactic acid is soluble in ether, and would be found along with, and increase the weight of, the fat; and for the further reason that it is almost impossible to satisfactorily dry the milk in the presence of the free acid, without producing a serious loss in weight from decomposition. The following method has been found to give very accurate results:

Three suitable platinum capsules, two of which are supplied

with glass-rods flattened at the ends, are weighed, and from 10 to 12 grams of sour milk, which has been thoroughly mixed by being whisked for a few minutes with a loose coil of fine brass wire, are introduced into each capsule, and the weight immediately ascertained. The separate quantities are exactly neutralized with pure decinormal soda solution, and the number of cubic centimetres required noted against each quantity. The contents of the two capsules containing the glass-rods are evaporated nearly to dryness, or until the residue attains the condition of a firm paste, a result which is promoted by occasionally stirring the contents towards the end of the evaporation.

The third portion is brought to complete dryness, and the amount of total solids and ash estimated.

The fat is extracted with ether in the usual way, and the non-fatty solids brought to complete dryness on the water-bath. On evaporation of the ether from the extracted fat no traces of any of the milk solids will be found in the fat, if the neutralization of the milk has been properly effected. When the weights of the non-fatty solids have been ascertained, a deduction must be made for the added soda solution. The increase of weight arising from the soda is shown in the following equation:

$$C_3H_6O_3 + NaHO = C_3H_5NaO_3 + OH_2$$
Lactic acid + Soda = Sodic lactate + Water.

Every unit, therefore, of acid is increased by one unit of sodium, less the weight of an atom of hydrogen, which it replaces in the acid. This, reckoned according to the atomic weights, is equal to 22. When, therefore, decinormal soda is used to neutralize the acid milk, every cubic centimetre used will add ·0022 gram to the milk solids, and this weight multiplied into the total cubic centimetres used will give the amount to be deducted. A similar deduction is also made in the case of the total solids. The deduction to be made from the ash is in accordance with the fact that the soda added is converted into carbonate of soda on

ignition of the milk residue, and the factor for multiplying into the number of cubic centimetres of soda employed is therefore ·0053 gramme. The following actual experiment will illustrate the method:

Milk taken for total solids = 9·517 grams.
7·0 c.c. $\frac{N}{10}$ soda-solution required to neutralize ∴ 7·0 × ·0022 = ·0154 grams.

Weight of dry total solids = 1·1390 grams.
Deduct ... ... ·0154 ,,

Milk solids ... ... 1·1236 ,,

$\frac{1·1236}{9·517} \times 100 = 11·80$ per cent. total solids.

Milk taken for Solids not Fat.

First Experiment.	*Second Experiment.*
Milk ... ... = 8·223 gms.	Milk ... ... = 8·728 gms.
Soda solution required = 6·000 c.c.	Soda solution reqird. = 6·40 c.c.
Dry residue ... = ·720 gm.	Dry residue ... = ·765 gm.
Deduct 6·0 × ·0022 = ·0132 ,,	Deduct 6·4 × ·0022 = ·01408 ,,
·7068 ,,	·75092 ,,
$\frac{·7068 \times 100}{8·223}$ = 8·59 per cent. of non-fatty solids.	$\frac{·75092 \times 100}{8·728}$ = 8·60 per cent. of non-fatty solids.
Dry fat = ·267 gm.	Dry fat = ·285 gm.
$\frac{·267 \times 100}{8·223}$ = 3·24 per cent. of fat.	$\frac{·285 \times 100}{8·728}$ = 3·26 per cent. of fat.

Ash residue ... ... = 0·110 grams.
Deduct 7·0 × ·0053 ... ... = ·0371 ,,

·0729 ,,

$\frac{·0729 \times 100}{9·517}$ = ·76 per cent. of ash.

The chlorine in the ash is estimated with $\frac{N}{10}$ silver-nitrate.

Required 3·0 c.c. to precipitate the Cl. $\frac{·00355 \times 3·0 \times 100}{9·517}$ = ·11 per cent. chlorine.

It is impracticable accurately to estimate the non-fatty solids by first taking the weight of the dry total solids and deducting the weight of fat obtained from it, as it is difficult to get a constant weight for the dry solids when the fat has not been removed. It is necessary, therefore, to rely on the actual weight

of the non-fatty solids, as these readily attain a constant weight without any sensible decomposition.

The allowance to be made for the loss which takes place in the non-fatty solids of milk is based upon the actual loss which has been found to occur in numerous samples of milk which have been analysed in the fresh state, and again at intervals, after the lapse of a certain number of days.

The depreciation or loss is fairly uniform for the same period of the year, but the amount varies within certain limits with the ordinary atmospheric changes of temperature, a slightly increased rate of depreciation occurring on a rise of temperature. The loss of non-fatty solids is relatively greatest during the first week of keeping, the amount for that period being on the average ·24 per cent.; for the second week the loss averages ·10 per cent. additional; and for each day thereafter ·01 per cent. According to this rate of allowance, the addition to be made to the non-fatty solids would be as follows for the number of days stated:

7 days	...	·24 per cent.
14 ,,	...	·34 ,,
21 ,,	...	·41 ,,
28 ,,	...	·48 ,,
35 ,,	...	·55 ,,

As already mentioned, a slight variation from these figures will be found, according to the conditions under which the milk has been kept; but the difference, whether greater or less, is generally indicated by the acidity of the milk, reckoned as lactic acid. With a carefully conducted analysis in the manner above described, the error, if any, in making the allowance should not exceed ·10 per cent. of the non-fatty solids, and, in the case of watered milk, the result should come within one per cent. of the quantity of water added, as previously estimated from the analysis of the fresh milk.

In the experiments upon the results of which these allowances are founded, the milk was kept in bottles filled to the extent of

about three parts, securely corked, and maintained at such temperatures as might be ordinarily expected to apply to official samples retained for reference under the Sale of Food and Drugs Act.

ADULTERATION.

The chief adulterant added to milk is water, but sugar, glycerin, carbonate of soda, salt, and salicylic acid, have also occasionally been used. These latter are obviously not added for the purpose of increasing the quantity of the milk. Some of them are used to cover the addition of water, and to render its estimation more difficult, and others to prevent the milk turning sour.

A variety of methods have from time to time been proposed for the analysis of milk, and some of them are of no little ingenuity. The process which is most widely adopted by analysts in this country, in connection with food analysis, has the merit of simplicity, and, at the same time, the results obtained are uniformly accurate if due care is exercised by the manipulator. This method of analysis, which consists in the determination of the fat, non-fatty solids, and ash respectively, is described on pages 9 to 14, and it is practically from a consideration of these three data that an opinion is formed of the character of a milk.

It would be comparatively easy if all milk were of uniform composition to pronounce upon a sample; but it will be seen from the following results of the analyses of nearly 240 samples that considerable variations occur in the composition of milk yielded by different cows.

The following samples fairly represent the ordinary range of variations that occur, and as the cows were, in all cases, milked in the presence of a responsible person, the genuineness of the milk in each instance can be authenticated:

TABLE V.—ANALYSES OF MILK.

Specific Gravity.	Percentage by Weight of				Percentage by Volume of Cream.
	Solids.			Ash.	
	Non-fatty.	Fat.	Total.		
1033·36	10·85	5·44	16·29	·69	11·00
1026·70	8·20	4·66	12·86	·65	14·00
1030·19	8·79	4·79	13·58	·71	3·25
1030·96	8·77	2·65	11·42	·69	3·25
1029·04	10·33	6·87	17·20	·87	25·00
1030·61	8·44	4·61	13·05	·69	6·50
1035·59	9·87	4·09	13·96	·85	11·00
1033·95	9·88	5·36	15·24	·77	15·50
1032·70	10·57	2·58	13·15	·69	4·00
1031·21	9·11	4·09	13·20	·69	12·00
1032·63	8·92	4·06	12·98	·65	5·50
1030·00	8·63	3·52	12·15	·64	7·00
1031·04	9·17	3·55	12·72	·68	3·50
1029·89	8·81	4·04	12·85	·66	9·00
1036·08	10·54	3·18	13·72	·75	4·50
1031·68	9·30	4·38	13·68	·81	9·00
1033·60	10·02	4·31	14·33	·75	8·00
1028·35	10·42	5·66	16·08	·77	19·00
1027·68	9·12	4·55	13·67	·79	6·50
1027·60	10·11	5·36	15·47	·77	7·75
1030·94	9·93	4·13	14·06	·75	5·00
1029·78	8·90	4·29	13·19	·78	20·00
1031·17	9·12	4·36	13·48	·80	14·00
1030·56	8·80	3·38	12·18	·73	10·50
1030·77	9·35	4·55	13·90	·82	14·50
1030·40	9·21	4·56	13·77	·71	5·00
1031·05	9·54	5·77	15·31	·69	17·50
1031·50	9·40	4·38	13·78	·83	12·00
1029·92	8·92	4·83	13·75	·65	11·00
1032·56	9·78	4·97	14·75	·76	21·00
1030·40	9·23	4·00	13·23	·75	11·00
1030·28	9·46	4·59	14·05	·74	25·00
1035·56	9·71	4·13	13·84	·79	12·00
1031·05	8·70	3·11	11·81	·78	7·50
1031·05	8·74	4·55	13·29	·71	14·00
1031·37	8·70	3·97	12·67	·73	14·50
1031·25	8·68	3·69	12·37	·74	13·00
1032·00	8·92	4·00	12·92	·69	5·00

TABLE V.—*continued.*

Specific Gravity.	Percentage by Weight of				Percentage by Volume of Cream.
	Solids.			Ash.	
	Non-fatty.	Fat.	Total.		
1031·53	9·23	6·22	15·45	·72	16·00
1030·56	8·63	3·50	12·13	·73	6·50
1033·20	9·88	4·43	14·31	·75	6·50
1031·21	9·16	3·76	12·92	·75	10·00
1033·09	9·29	2·47	11·76	·84	7·25
1032·92	9·28	4·17	13·45	·78	8·25
1033·70	9·29	3·45	12·74	·77	5·00
1032·61	9·08	3·55	12·63	·78	10·00
1031·60	8·58	3·70	12·28	·66	6·50
1030·61	8·60	2·67	11·27	·71	8·00
1030·99	8·97	2·71	11·68	·73	6·25
1032·00	9·09	3·32	12·41	·67	8·00
1030·50	8·50	3·22	11·72	·69	7·50
1032·37	8·95	2·25	11·20	·75	4·00
1031·90	9·12	2·53	11·65	·76	9·00
1029·90	9·03	3·99	13·02	·71	5·00
1031·29	8·94	4·10	13·04	·66	5·50
1030·00	8·89	3·86	12·75	·67	8·00
1029·02	8·38	2·95	11·28	·63	Coagulated.
1030·50	8·74	3·60	12·34	·62	7·00
1028·85	8·50	3·36	11·86	·75	9·00
1030·30	8·64	3·75	12·39	·65	5·50
1029·30	8·74	4·08	12·82	·66	13·00
1029·23	9·06	3·45	12·51	·79	5·25
1029·20	8·90	4·99	13·89	·71	9·00
1030·15	9·02	4·68	13·70	·72	18·00
1030·94	9·41	5·27	14·68	·74	11·00
1027·92	8·23	4·90	13·13	·67	9·00
1029·30	8·81	4·85	13·66	·75	7·50
1034·88	10·13	3·88	14·01	·78	9·00
1030·19	8·98	2·29	11·27	·72	3·50
1029·40	8·59	2·26	10·85	·73	2·00
1030·49	8·95	2·91	11·86	·72	2·50
1027·67	8·58	3·73	12·31	·79	8·00
1027·53	8·34	4·34	12·68	·69	5·50
1030·20	9·37	3·91	13·28	·69	9·00
1029·52	8·46	3·09	11·55	·68	6·00
1028·78	8·90	3·11	12·01	·70	7·50
1031·35	9·05	4·16	13·21	·66	7·50
1028·85	8·70	4·41	13·11	·65	8·00

TABLE V.—*continued.*

Specific Gravity.	Percentage by Weight of				Percentage by Volume of Cream.
	Solids.			Ash.	
	Non-fatty.	Fat.	Total.		
1028·72	8·48	4·24	12·72	·71	10·50
1032·05	9·49	4·73	14·22	·71	5·00
1027·05	8·00	2·31	10·31	·62	3·00
1031·71	9·54	3·23	12·77	·75	7·00
1029·34	8·54	2·78	11·32	·65	5·00
1030·14	8·86	2·31	11·17	·72	5·00
1030·00	8·66	2·19	10·85	·76	3·50
1029·02	8·83	4·57	13·40	·67	4·50
1029·27	8·31	3·39	11·70	·66	5·00
1031·25	9·21	4·20	13·41	·72	7·00
1031·40	9·66	3·19	12·85	·71	9·00
1028·13	8·02	3·65	11·67	·71	7·00
1029·03	8·81	4·54	13·35	·65	9·50
1031·26	8·89	3·00	11·89	·73	5·50
1031·25	9·16	4·87	14·03	·72	12·00
1030·38	8·69	3·75	12·44	·69	8·50
1028·76	8·37	3·76	12·13	·77	7·00
1029·82	8·87	4·77	13·64	·76	6·50
1029·74	8·80	3·77	12·57	·72	6·00
1028·39	8·53	4·57	13·10	·71	12·00
1029·76	8·59	2·83	11·42	·78	6·00
1028·78	8·72	4·77	13·49	·71	8·00
1028·40	8·42	4·23	12·65	·74	5·50
1029·11	8·71	3·82	12·53	·74	11·00
1028·47	8·58	3·90	12·48	·76	11·00
1027·54	8·49	4·66	13·15	·74	5·00
1028·50	9·08	4·33	13·41	·70	11·00
1029·41	8·48	3·67	12·15	·77	9·00
1029·31	8·33	3·17	11·50	·74	5·50
1031·31	9·20	3·90	13·10	·78	6·00
1028·94	8·77	3·08	11·85	·77	11·00
1027·90	8·01	2·42	10·43	·69	3·50
1030·46	8·66	2·77	11·43	·68	6·00
1027·71	9·49	6·20	15·69	·76	24·00
1027·32	8·54	4·94	13·48	·68	15·00
1028·30	8·43	3·17	11·60	·71	9·00
1033·26	9·40	2·93	12·33	·70	10·00
1032·38	9·10	2·56	11·66	·70	6·00
1032·88	9·07	1·92	10·99	·73	5·00
1028·69	8·52	3·63	12·15	·68	11·00

TABLE V.—*continued.*

Specific Gravity.	Percentage by Weight of				Percentage by Volume of Cream.
	Solids.			Ash.	
	Non-fatty.	Fat.	Total.		
1031·57	10·31	4·55	14·86	·73	10·00
1031·40	9·90	4·92	14·82	·76	15·00
1033·05	10·44	4·69	15·13	·70	22·00
1031·12	9·75	5·14	14·89	·76	15·00
1030·86	9·26	4·84	14·10	·72	10·00
1030·80	9·15	4·80	13·95	·75	19·00
1031·80	9·00	2·96	11·96	·70	10·00
1032·50	9·45	2·47	11·92	·69	5·50
1034·86	10·08	3·64	13·72	·76	6·00
1030·72	8·60	3·29	11·89	·67	6·00
1033·37	9·71	3·64	13·35	·69	5·00
1033·40	9·81	4·49	14·30	·77	15·00
1032·29	9·84	3·23	13·07	·77	10·00
1031·69	8·93	3·52	12·45	·70	9·00
1032·98	9·27	3·88	13·15	·72	5·50
1034·08	9·79	3·84	13·63	·74	10·00
1031·27	9·40	3·27	12·67	·74	8·00
1030·17	8·87	3·50	12·37	·70	5·50
1030·10	8·91	3·24	12·15	·72	5·50
1029·93	9·11	4·32	13·43	·78	26·00
1030·58	8·95	3·01	11·96	·68	9·00
1028·97	8·83	4·05	12·88	·64	7·00
1031·21	9·28	3·68	12·96	·68	9·00
1029·95	8·77	3·91	12·68	·65	4·50
1030·59	8·92	3·83	12·75	·68	14·50
1028·19	8·09	3·78	11·87	·76	7·00
1029·05	8·36	3·88	12·24	·68	10·00
1029·88	8·90	3·93	12·83	·78	15·50
1031·21	9·11	2·89	12·00	·79	10·00
1034·21	9·60	2·44	12·04	·79	6·00
1032·57	9·33	2·64	11·97	·70	11·50
1034·26	9·94	3·08	13·02	·73	8·00
1036·94	10·58	3·67	14·25	·79	20·00
1031·77	9·40	4·46	13·86	·70	17·00
1031·72	9·05	2·94	11·99	·68	5·50
1032·06	9·61	4·72	14·33	·70	12·00
1031·41	9·15	4·03	13·18	·70	6·00
1030·44	9·01	4·82	13·83	·72	9·50
1031·36	9·32	4·10	13·42	·72	6·50
1033·40	10·75	4·10	14·85	·70	8·00

TABLE V.—*continued.*

Specific Gravity.	Percentage by Weight of				Percentage by Volume of Cream.
	Solids.			Ash.	
	Non-fatty.	Fat.	Total.		
1031·81	9·79	3·62	13·41	·74	10·00
1032·99	10·33	4·25	14·58	·72	15·00
1031·10	9·63	4·48	14·11	·80	11·00
1031·72	9·90	4·50	14·40	·76	10·00
1033·44	9·52	3·01	12·53	·72	11·00
1034·41	10·38	3·40	13·78	·79	9·00
1033·66	10·13	4·83	14·96	·76	17·00
1033·70	8·97	3·31	12·28	·68	7·50
1033·47	9·93	3·37	13·30	·67	6·00
1033·34	9·56	3·35	12·91	·78	6·00
1032·40	9·32	3·88	13·20	·68	9·00
1033·84	10·50	3·78	14·28	·84	10·00
1033·82	9·89	2·62	12·51	·70	7·00
1033·32	9·50	3·80	13·30	·69	9·00
1031·32	8·91	3·11	12·02	·62	3·50
1031·40	8·77	2·65	11·42	·66	3·00
1030·80	8·70	3·45	12·15	·63	6·00
1031·26	8·77	3·31	12·08	·71	2·00
1030·42	8·60	3·46	12·06	·65	3·00
1028·30	8·65	4·11	12·76	·63	11·00
1030·20	9·54	3·35	12·89	·71	8·50
1035·20	10·58	3·16	13·74	·75	13·00
1031·70	9·75	2·50	12·25	·67	5·50
1032·80	9·90	4·41	14·31	·76	18·00
1028·90	8·43	3·22	11·65	·67	6·00
1029·50	8·39	2·97	11·36	·70	14·00
1030·80	8·66	2·27	10·93	·62	3·00
1032·43	9·35	2·34	11·69	·77	12·00
1032·28	9·65	3·15	12·80	·79	15·00
1031·50	9·29	3·09	12·38	·68	12·00
1030·95	10·00	2·69	12·69	·72	13·00
1031·71	9·61	4·58	14·19	·68	16·00
1031·48	9·25	2·50	11·75	·70	13·00
1031·72	9·65	2·59	12·24	·78	13·00
1034·65	10·55	2·51	13·06	·76	17·50
1029·37	8·66	3·51	12·17	·63	8·00
1029·00	8·83	3·25	12·08	·66	9·50
1031·52	9·36	3·12	12·48	·66	2·00
1034·20	10·44	2·20	12·64	·80	8·00
1033·20	9·86	2·52	12·38	·75	8·00

TABLE V.—*continued.*

Specific Gravity.	Percentage by Weight of				Percentage by Volume of Cream.
	Solids.			Ash.	
	Non-fatty.	Fat.	Total.		
1032·90	10·25	3·07	13·32	·77	14·00
1028·80	8·38	3·18	11·56	·74	7·00
1031·70	9·25	2·59	11·84	·72	7·00
1032·90	9·34	2·59	11·93	·78	6·50
1028·20	8·33	3·80	12·13	·73	9·00
1029·90	9·36	4·04	13·40	·74	9·50
1030·30	10·34	3·99	14·33	·77	15·00
1029·80	9·19	5·73	14·92	·78	15·00
1032·90	11·27	3·99	15·26	·87	—
1031·90	9·56	3·69	13·25	·71	11·00
1030·40	8·83	3·02	11·85	·76	6·00
1030·60	8·93	2·93	11·86	·72	2·00
1031·70	10·01	3·81	13·82	·75	10·00
1031·10	9·83	2·76	12·59	·76	16·00
1032·10	9·43	3·41	12·84	·76	8·00
1032·90	9·77	4·15	13·92	·69	15·00
1028·70	8·87	4·83	13·70	·67	16·00
1031·50	9·18	4·15	13·33	·73	12·50
1029·60	8·77	3·83	12·60	·76	12·00
1029·10	8·28	3·46	11·74	·73	8·00
1031·00	8·90	3·79	12·69	·78	10·00
1032·30	9·94	6·05	15·99	·79	11·00
1031·20	9·33	5·32	14·65	·71	14·00
1030·90	9·26	5·07	14·33	·72	7·00
1033·60	9·79	4·30	14·09	·82	—
1029·80	9·10	6·79	15·89	·72	—
1030·30	8·74	3·56	12·30	·76	—
1033·00	9·63	5·25	14·88	·75	—
1033·50	9·28	4·87	14·15	·83	—
1032·10	9·51	5·57	15·08	·76	—
1029·90	8·83	5·41	14·24	·74	—
1030·40	8·78	4·14	12·92	·64	—
1032·90	9·33	3·51	12·84	·70	—
1030·30	9·15	5·20	14·35	·69	—
1029·50	8·90	4·95	13·85	·69	—
1032·60	9·13	2·60	11·73	·72	—
1030·10	9·10	5·86	14·96	·69	—
Average ...	9·00	3·83	12·83	·71	—

TABLE VI.—DAIRY SAMPLES.

Specific Gravity.	Percentage by Weight of				Percentage by Volume of Cream.
	Solids.			Ash.	
	Non-fatty.	Fat.	Total.		
1031·70	9·55	5·14	14·69	·63	16·0
1031·61	9·57	4·83	14·40	·77	14·0
1030·73	9·10	4·62	13·72	·65	16·0
1033·05	9·28	3·99	13·27	·73	8·0
1031·51	8·70	3·21	11·91	·72	5·5
1029·88	9·05	4·05	13·08	·72	10·0
1031·05	9·23	4·40	13·63	·74	13·0
1029·76	8·50	3·65	12·15	·74	9·5
1029·93	8·62	3·66	12·28	·69	9·0
1029·46	8·70	4·37	13·07	·70	7·5
1030·91	8·88	3·38	12·26	·74	7·0
1028·91	8·80	3·28	12·08	·65	—
1030·72	8·82	2·95	11·77	·78	6·0
1031·35	9·00	3·66	12·66	·67	6·0
1029·15	8·50	3·37	11·87	·65	7·0
1030·70	9·91	3·58	13·49	·76	10·0
1031·00	9·60	3·62	13·22	·72	12·0
1031·60	9·51	4·70	14·21	·78	13·0
1031·60	9·30	4·58	13·88	·75	—
1031·00	9·14	5·10	14·24	·75	—
1030·40	8·82	4·42	13·24	·74	—
1031·40	9·16	4·43	13·59	·78	—
1029·80	8·80	4·98	13·78	·67	—
1029·70	8·81	4·99	13·80	·69	—
Average ...	9·01	4·12	13·22	·72	—

NOTE.—"The results of our investigation into the composition of genuine milk, as recorded in the above tables, are in agreement with those recently obtained by several well-known analysts.

According to a Paper by Chas. A. Cameron, M.D., in one case, in which the milk of a herd of 42 cows was analysed, it was found that 25 of the cows yielded milk which contained less than 9 per cent. of non-fatty solids, the minimum being 8·25 per cent. The analyst's conclusion was that, so far as house-fed cattle in Ireland are concerned, the standard of 9 per cent. should be reduced to 8·5 per cent.—"The Analyst," vol. vi., No. 62, May, 1881.

It will be seen from Table V. above, that in the case of individual cows the non-fatty solids vary from 8·00 to 11·27, the fat from 1·92 to 6·87, and the ash from ·62 to ·87 per cent., while in the case of dairy samples in Table VI., the non-fatty solids vary from 8·50 to 9·91, the fat from 2·95 to 5·14, and the ash from ·63 to ·78 per cent. The percentage of chlorine in the samples taken as a whole varies from ·08 to ·14 per cent.

Although these variations are considerable, it cannot be affirmed that they cover every case of low non-fatty solids which is occasionally met with in the milk of an individual cow.

In another case B. Dyer, F.C.S., remarking upon the results of some analyses of genuine milk, says: "The fact that an individual cow in good health and well fed can frequently give milk yielding on an average only 8·7 per cent. of solids not fat,' should make us cautious in giving certificates of adulteration." —"The Analyst," vol. vi., No. 61, April, 1881.

In a third instance Dr. P. Vieth stated that in a herd of 120 cows in Raden, in Germany, the average yield of non-fatty solids, for the years 1879–80, fell in most cases between 8·5 and 9·0 per cent., and that they never rose above 9·0, but fell occasionally below 8·5 per cent. In the case of individual cows the non-fatty solids varied as a rule from 8 to 9 per cent., but they sometimes fell below 8·0, and in a few instances they rose above 9·0 per cent.

At Kiel, the average of the milk of 10 cows was as follows:

In 1878,	non-fatty solids,	8·73	per cent.
,, 1879	,,	,,	8·71	,,
,, 1881	,,	,,	8·53	,,

At Proskau, in 1879, the average of non-fatty solids was 8·42 per cent. Dr. P. Vieth further stated, as the result of eighteen months' experience in England, that 9·0 per cent. as a standard for non-fatty solids is too high, and recommends the adoption of 8·5 as a standard for non-fatty solids.—"The Analyst," vol. vii., No. 73, April, 1882.

Lastly, Otto Hehner, F.C.S., in directing attention to the different methods of milk analysis practised, showed from his own experiments that the Wanklyn method, by which the limit of 9 per cent. of non-fatty solids was arrived at, would not give more than 8·5 per cent. by other methods now in use, and among these that of drying the solids to a constant weight; and he adds that "It appears to me that as much more concordant results are obtained when the solids are dried to constant weight than for three hours only, it would be well to discard the old plan, and, accordingly, to lower the limit of 'solids not fats' from 9·0 to 8·5 per cent."—"The Analyst," vol. vii., No. 73, April, 1882.

We have always considered that there was an advantage in drying the solids to a constant weight, and hence we have followed this method in all our milk analyses, as stated on page 9.

Where such natural variations occur in the composition of an article, much valuable assistance is gained in dealing with a suspected sample by carefully comparing the results of the analysis of the milk with the proportions in which the non-fatty solids, fat, and ash are found in genuine milk samples.

It appears reasonable that in deciding whether a milk contains added water or not, there must be an advantage in taking the whole of the constituents into account, instead of the non-fatty solids only. Although the amount of fat in some cases of watered milk may not be very low, yet a small percentage may sometimes afford valuable corroborative evidence of the addition of water. In like manner the amount of ash frequently affords a useful factor in coming to a conclusion respecting a sample. If the ash should be low in a milk which is also low in non-fatty solids, that fact would serve to confirm the suspicion that water had been added.

Instead of adopting the principle of a general comparison of the analytical results, it is the practice with most analysts to fix limits of quality, founded upon the amounts of non-fatty solids and fat respectively, and to regard all milk falling below the lines laid down as either watered or robbed of cream, as the case may be.

For the purpose of deciding whether water has been added to milk, some analysts fix 9·3, and others 9·0 per cent. of non-fatty solids as limits, below which milk should be reported as containing added water. It will be seen, however, from the results of the analyses in the above tables, that whilst many samples reach 9·0 and 9·3 per cent. of non-fatty solids, and some rise even considerably higher than the latter, a large proportion fall below these figures; and this is true not only of the milk of individual cows, but also to a considerable extent in the case of dairy samples. It is therefore obvious that when nothing is known of the history of a milk, the adoption of such a high standard for non-fatty solids might bring perfectly genuine

samples under the category of watered milk, and a great hardship would thus be inflicted on innocent persons.

It is difficult to suggest a definite *minimum* limit for non-fatty solids which could be fairly applied to all milk, but the results of the analyses of dairy samples in Table VI. will serve to convey some idea of the ordinary range which may be expected to be met with in such solids in commercial samples. In dealing, however, with a suspected milk, due consideration should be given to the fact that still larger variations occur in the composition of the milk of individual cows, also to the possibility of an ordinary dairy sample being somewhat exceptional, and the non-fatty solids falling below 8·5 per cent.

Some persons urge that all samples should be judged by milk of average quality, while others contend that such limits should be adopted that when a milk is met with which falls below the standard, there should be no doubt, from the results of the analysis alone, that the milk was not genuine.

The adoption of the first view would be unjust to the milk-seller, and that of the second unfair to the consumer. Average milk, according to the results in Tables V. and VI., ranges in non-fatty solids from 9·0 to 9·1 per cent., in fat from 3·83 to 4·12, and in ash from ·71 to ·72 per cent.; and it is obvious that these figures could not be properly applied to milk of poor or medium quality, both of which, as shown by the tables referred to, appear to be produced to a considerable extent, as shown from the results of the analyses of the milk in the tables.

It would be equally unfair to adopt as a standard the lowest quality of milk that has been met with, as this would tend in some instances to cover the addition of water to rich milk without a prospect of the results of the analysis indicating the fraud, and in other cases it would practically exclude the analyst from pronouncing against samples which afforded evidence of having been obviously reduced in quality by added water.

The application of a uniform standard, which would operate

alike fairly to consumer and vendor, to a natural product like milk, having a wide range of quality, is a problem of which a satisfactory solution may be almost regarded as impossible. Milk, however, does not stand alone in this respect; butter, for example, has naturally a range of quality equally extensive, and again, tea yields very different percentages of extractive matter and soluble ash.

To meet the difficulty the adoption of two milk standards has frequently been suggested; and if it were practicable to fix or legalize two standards of quality, the whole difficulty of deciding upon the character of a sample would resolve itself into a question of accuracy of analysis, but the plan would not be unattended with some serious drawbacks. Two standards would presume that every dairyman and milkseller would not only be accurately informed as to the analytical results of the milk from his own cows, but also of those yielded by the milk of the cows of any other farm or dairy from which he may be accustomed to draw his supplies.

The existence of two standards would also inevitably lead to the establishment of large centres of distribution, and the systematic reduction of nearly all milk to the lower standard of quality; and any plan which would admit of the watering of milk would strike at the very root of the Sale of Food and Drugs Act, which admits of no addition to, or abstraction from, the milk whatever.

It is to be feared that the abstraction of cream from milk is often practised without being discovered, as some milks contain more than twice as much fat as others; it is evident that a considerable proportion of cream can be removed from rich milk without raising any suspicion of the fact. Fat being the most valuable constituent of milk, a deficiency of 1 per cent. is a much more serious depreciation in the value of the article than that of a corresponding weight of the non-fatty solids.

The possession of the means of arriving at certain proof of

the abstraction of small quantities of cream from milk would be a great point gained, but owing to the wide variations which occur in the proportions of fat, it becomes a very difficult matter to affirm that a milk has been deprived of cream, unless the quantity of fat remaining is reduced to rather a low percentage.

The lowest amount of fat which we have found in a dairy sample was 2·95 per cent.; but having regard to the number of cows which yield poorer milk, as will be seen from the results recorded in Table V., it would be difficult to support a higher minimum limit than 2·4 per cent.

It may occasionally occur that a milkseller, through want of care in rousing his milk at the time of sale, may supply a sample which on analysis shows a quantity of fat below that which would be yielded by the milk if the cream had been uniformly diffused through it. The purchaser, however, has a right to expect that proper precautions shall be taken by the seller, so as to insure that the milk supplied from the same vessel is practically of uniform quality.

Salt.—Salt is occasionally employed to cover the addition of water, and its presence is indicated by the high amount of chlorine obtained on testing a solution of the ash with a decinormal solution of silver nitrate. Any proportion of chlorine over ·14 per cent. points to the presence of salt. A tedious, but much more conclusive test for salt, is to estimate the quantity of soda as well as that of the chlorine. As milk does not contain more than ·04 per cent. of soda, any material increase found above this quantity would indicate the presence of a soda-salt.

Carbonate of Soda.—This is sometimes added to neutralize any sourness in rather old milk, and also to keep fresh milk sweet for a longer time than usual. Its presence would be indicated by the milk giving a high ash, and by the latter effervescing on the addition of a little acid. As the ash of cow's milk, when pure, gives no distinct indication of the presence of carbonates, the

envelope, enclosing the fatty globule, the character of which has been already referred to, and to the presence of independent albuminous cells, or nuclei, all of which tend to affect the relative proportions of caseous matter to water in the cream.

The cream is ordinarily separated in the cold from the milk after the latter has stood for a period of from twelve to twenty-four hours; but in the preparation of clotted or Devonshire cream, the milk is allowed to remain for about twelve hours, and is then heated over hot plates, by which means a slight coagulation of the albuminous matter takes place, and a more complete separation of the cream is effected, while, at the same time, a much smaller proportion of the milk is removed along with it.

The separation of cream from milk can be effected in a very short time by means of the patent cream separator recently brought into use. The milk is placed in a horizontal rotating vessel, driven at the rate of 6000 revolutions per minute, which causes the heavier milk fluid to gravitate towards the circumference of the vessel, whilst the cream remains nearer the centre, and rises towards the upper part of the rotating bowl, whence it is removed by a conveniently-placed aperture on the side of the vessel. An exit is also provided for the gradual removal of the skimmed milk, thus making room for fresh milk to be added to the apparatus, and allowing the process to be carried on continuously. A vertical rotating cream separator has been devised since the one described was patented, and certain advantages are claimed in respect of the new apparatus, chiefly on the ground that it is as effective in the separation of the cream as the existing one, with a greatly reduced rate of speed.

The following table contains the results of the analyses of several samples of ordinary commercial cream:

TABLE VII.—ANALYSES OF COMMERCIAL CREAM.

Samples.	Description.	Percentage of				
		Water.	Fat.	Milk Sugar.	Casein.	Ash.
1	Raw Cream ...	54·02	39·40	1·85	3·76	·57
2	,, ,, ...	60·66	33·60	2·43	2·90	·41
3	,, ,, ...	67·93	24·44	2·96	4·04	·63
4	,, ,, ...	58·07	35·67	2·20	3·55	·51
5	,, ,, ...	63·07	30·74	2·61	3·04	·54
6	Thick Cream ...	37·62	58·77	1·46	1·83	·32
7	Devonshire Clotted	33·76	59·79	1·01	4·97	·47

It will be seen from the results recorded in the above table, that the variations in the quality of commercial creams are very considerable, and that if the percentage of fat be taken as the basis of calculation, the five samples of ordinary cream will be found to differ from 25 to 144 per cent. in value from each other. Nos. 2 and 6 were separated from the milk by the vertical cream separator, and a notable feature about them is the relatively small proportion of casein which they contain, especially in the case of the sample of thick cream.

Cream stands on a somewhat different footing from milk, as it is limited in consumption, and is essentially a luxury, and the purchaser can by simple inspection form a fairly accurate opinion as to its quality; while in the case of milk a person could not do this without subjecting the sample to some process of analysis.

In order to always produce substantially the same quality of cream, it would be necessary either to have an efficient cream separator, or refrigerating rooms, which could be maintained at a uniform temperature throughout the year. In winter, milk can be left for twelve or twenty-four hours to throw up its cream, without

suffering deterioration, and a thick rich layer forms on the surface within that time, and can be readily separated; but in summer, under ordinary circumstances, milk could not be safely kept for more than eight or nine hours without danger of its becoming sour, and the cream collected at the surface during that time would be comparatively thin and poor. In these circumstances it is probable that it would be considered a hardship to insist upon a standard for cream, unless a low limit were adopted; and this would be undesirable in the interests of the public, as it might lead to their being supplied with a poorer quality of cream than at present.

CONDENSED MILK.

Condensed, or preserved, milk is prepared from that of the cow or goat by the addition of sugar and evaporation of a portion of the water equal to three-fourths of the original volume of the milk. There is also a variety of condensed milk made without the addition of sugar; but, unlike the former, it does not remain sweet for any length of time after exposure to the air.

Condensed milk is a white sirupy fluid. It mixes freely with water in all proportions, and has a characteristic flavour which differs from that of the fresh milk.

Its preparation is generally conducted as follows: The milk is first strained, and then heated to a temperature of 150° F. (65·5° C.) to 175° F. (79·4° C.) by placing the cans containing the milk in hot water. The milk is afterwards passed through strainers, and then conveyed into a vat fitted with steam-pipes, by which it is raised to the boiling temperature. Sometimes the evaporation is conducted under diminished pressure in a vacuum pan.

An addition of refined sugar is made during the boiling in the proportion of 1 lb. to 1¼ lb. for every quart of the condensed milk produced. The operation of condensing the

milk occupies about three hours, at the end of which time the product is drawn off into cans, cooled to about 70° F. (21·1° C.), and then immediately weighed into tins, which are soldered down.

It has been observed that when milk, from which the cream has been partly removed, is employed in the manufacture of condensed milk, the product looks better and is more pleasant in flavour than when a rich milk is used.

In the results, however, obtained from the samples of milk given in the table, there is not much evidence that any serious abstraction of cream has taken place.

TABLE VIII.—ANALYSES OF CONDENSED MILKS.

Description.	Percentage of				
	Water.	Fat.	Cane and Milk Sugar.	Casein.	Ash.
Swiss	26·70	9·76	51·02	10·20	2·32
English	27·07	8·30	50·79	11·84	2·00
Pure Swiss Milk, Condensed ...	61·40	11·37	13·37	11·48	2·38
Pure Condensed Alpine Milk ...	62·35	11·15	13·14	11·29	2·07

The analysis of condensed milk is conducted like that of ordinary milk, with the exception that, in order to estimate the total sugar, the percentage of milk-sugar should be ascertained before inversion of the cane-sugar, otherwise the final estimation of the two kinds of sugar after boiling with mineral acid will give a result rather below the true quantity. This arises from the fact previously stated, that the copper-reducing power of milk-sugar, after inversion, is lower than that of dextrose.

BUTTER.

Origin.—Butter consists of the fat of milk, and chiefly of that derived from the milk of the cow. The fat exists in the state of minute globules suspended in the milk-liquid, and when it is left at rest the globules rise and form a layer on the top. This layer, which is mixed with a considerable portion of casein and milk-fluid, forms the cream, and is easily separated by skimming

The globules of fat vary greatly in size, and the largest ones rise to the surface first, the medium ones next, and so on. The entire cream of milk, therefore, consists of several layers of fat globules of different sizes. A vast number of the very minute globules never reach the surface at all, as they do not possess sufficient buoyancy to rise through the mass of milk, and consequently occupy different positions in the body of the fluid, corresponding to their various degrees in size. It is for this reason that skim-milk is always found to contain a certain proportion of fat globules, but minute in size, some presenting the appearance of mere specks when viewed under high magnifying powers.

The fat globules have been regarded by some authorities as consisting of cells surrounded by a skin or membrane; while

others have considered them as particles of fat round which local attraction has formed a layer of casein or condensed fluid. The results of our own investigations tend to confirm the latter view, and point to the fact that the fat is present in the milk in a state of emulsion. The globules of fat, which, as stated before, are of different sizes in the same milk, vary also in size with the breed of the cow, and even in the milk of the same cow they become smaller as the time elapses from calving. Those in the milk of the Alderney cow are above the average size, and they readily rise to the surface as cream. The difference in the size of the globules in different milks is generally indicated by the length of time required for the cream to rise, for the smaller the globules the more slowly does the cream form.

Description.—Commercial butter is more or less granular, and the more perfect the granular condition the higher is its quality considered. Butter varies in colour both with the breed of the animal and its food, ranging from a nearly white to a deep yellow. A good butter when fresh has a pleasant odour and an agreeable taste, but the flavour, like the colour, varies with the food, and it is much stronger when the cow is fed on mangel wurzel or Swedish turnips than on hay or grass. Butter prepared from the milk of some other animals, such as the goat, naturally possesses, irrespective of food, a strong peculiar taste.

At ordinary temperatures butter is easily cut or moulded into fancy shapes, and it readily melts to a transparent light-coloured oil. It always contains more or less curd, which is very liable to undergo decomposition, and hence the reason for the addition of salt, which acts as a preservative.

When butter fat is freed from curd and water it possesses considerable permanence of character, and if fairly excluded from the air, it may be kept for a long time without any appreciable change. The curd and water may be separated by melting the butter in a suitable vessel, when the butter fat, which floats on

the top, may be readily poured or drawn off from both the curd and the water, which remain at the bottom.

The method of butter-making followed for many generations in this country was extremely crude and primitive, and even now, in some districts, the system pursued is comparatively rude, and but little calculated to produce a first-class article. It is only within the last sixty or seventy years that improved utensils and appliances have been introduced into the dairy, and that any decided improvements have been made in the method of treating milk in butter-making.

At one time milk was kept in rooms used for a variety of purposes, and no attention whatever was paid to temperature or ventilation, and the vessels employed were made of wood, and therefore difficult to keep sweet and clean. The wooden vessels have been gradually replaced by brown earthenware pans, glazed inside; and these again have been largely superseded by pans made of tin or galvanized iron.

The creaming of milk is an important part of the manufacture of butter, and although everyone is more or less acquainted with the natural process by which cream rises, few have studied the subject and the influences by which it is effected. For some years past however considerable attention has been given to the subject, and several methods of treating the milk for creaming have been devised with more or less success. A system invented by a Swede named Swartz has made considerable progress, and it is now almost universally adopted throughout a great portion of northern Europe. This method of treatment is called the "ice-water system," and it consists in setting deep cans containing the milk in cold or ice water to cream. The cans containing the milk are placed in tanks or cisterns, and the cold water surrounds the outside of the cans to the height of the milk inside. If the water is not cool enough it is made so by the addition of ice or snow, and the temperature is maintained at from 40° F. (4·4° C.) to 50° F. (10° C.), the object being not only to produce

the largest possible quantity of cream, but also to obtain it in that pure and sweet condition which is so essential to the production of butter of fine flavour.

Various modifications of this system have been introduced, but they are all based on the cooling principle, and differ only from the Swartz system in the mode of applying the process. The most prominent among these modifications are the Cooley and Hardin systems. In the Cooley method, which prevails to a large extent in America, the water not only surrounds the can outside as high as the milk inside, but is made to rise an inch or two above the lid, so that the can is completely submerged, and all contamination from external sources prevented.

The Hardin system, like the foregoing, is based on the Swartz system; but ice, and not ice-water, is employed as the cooling agent. The cans are placed in a confined space, and subjected to the influence of air cooled by ice instead of ice-water; and the originator claims that by this method there is greater economy of ice, and that the cream is obtained in a more solid condition.

The cream rises by reason of its having a less specific gravity than the milk fluid with which it is mingled; and as the fat globules expand and contract more than the milk fluid with heat and cold, it follows that the difference between the specific gravity of milk and cream is greatest when the milk is warm, and least when it is cold, and hence the cooling of milk prior to setting it to cream *retards* the creaming. But if the milk be set to cream while warm from the cow, then the gradual cooling of it to 40° F. (4·4° C.) or 50° F. (10° C.) *expedites* the rising of the cream, because, as water is a better conductor of heat than fat, the milk fluid is first affected, and the increased difference in specific gravity thus caused, though slight, is sufficient to hasten the rising of the cream in a very appreciable degree.

In the ice-cooling system, where deep vessels are used, the cream does not separate so completely as it does in the shallow pan-setting system. The cream all rises into the upper portion of

the milk, but it remains intermixed with a greater proportion of milk fluid, and is thinner than cream that has been produced in the ordinary way from milk set in shallow pans.

In some parts of the West of England, and particularly in Devonshire, the milk is set aside overnight in pans about nine inches deep, to cream in the ordinary way. The following morning the pans are set upon hot plates, and the milk raised in the course of about an hour to near the boiling point, care being taken not to disturb the layer of cream. The milk is then set aside to cool, after which the cream, now called "Devonshire" or "clotted cream," is skimmed off, and either used as such or churned into butter.

It is probable that cream separators, such as those referred to on page 34, will in time become generally adopted in dairies, and, if so, the present difficulties of satisfactorily creaming the milk will be practically obviated, and sweet cream be always obtained.

On small farms the butter is formed by simply stirring the cream in a shallow tub with the hand, and for this purpose a cool hand is considered an indispensable qualification in a Devonshire dairymaid.

In butter-making the usual course now is to skim the milk, and churn the cream by itself, but at one time the general practice was to put the milk aside until it became more or less sour, and then to churn the entire bulk of the milk. This practice still prevails to a large extent among many small farmers in different parts of the kingdom, and especially in the neighbourhood of towns where there is a demand for buttermilk.

The coalescence of the fat globules may be effected by heating the milk to near the boiling-point, when the particles of fat rise to the surface, melt, separate from their surroundings, and unite, forming a layer of melted fat on the surface of the milk fluid. This is said to be the method followed in some hot climates to avoid the labour of churning, but in butter-making

the aggregation of the fat globules of the milk is almost universally effected by mechanical means.

In the actual process of the manufacture of butter a variety of churns are employed, each country, and occasionally a district of country, having one or more favourite kinds.

It is said the most perfect churn is one in which, by its construction, the agitation of the cream or milk is uniform, or as nearly as possible uniform, throughout the mass; the chief object being to effect a transformation of the whole of the fat into butter about the same time. When the agitation is unequally distributed throughout the mass, the fat is liable to be converted into butter at different times, and the portions formed at the earlier stages of the process will be beaten into a soft mass, and the finished butter thereby deteriorated by losing its granular appearance.

At the time of churning it is necessary to pay particular attention to the temperature of the milk. The temperature considered most suitable is 60° F. (15·5° C.), and if it falls below 55° F. (12·7° C.) the labour of churning is greatly increased even in the summer. In winter the temperature may be raised to 65° F. (18·3° C.), or in very cold weather to 70° F. (21·1° C.), without causing any injury. It is stated that when the cows are fed on dry food there is greater difficulty in churning than in the summer, when they are fed on grass.

Cream that is a little sour is more easily churned at a lower temperature than fresh cream; but when cream is very sour the churning becomes more difficult, the quantity of butter is diminished, and its flavour seriously affected.

History.—Butter appears to have been known from very early times. By the Jews it was extensively used as food, but by the Greeks and Romans it was chiefly employed as an ointment for the body, and in southern Europe it is still sold by apothecaries for external application. Pliny speaks of butter as being much valued

by barbarous nations, among whom its use served to distinguish the rich from the poor. He adds that it was prepared by agitating cow's, goat's, or ewe's milk in long vessels, with narrow necks. There is undoubted evidence that butter was well known to the Anglo-Saxons, for there are many references to its use in the preparation of their salves and medicines. Goats and sheep, however, appear to have furnished the bulk of their supplies, and *cow* butter is frequently mentioned by way of distinction.

CHEMICAL COMPOSITION.

Butter consists of a mixture of fatty acids in combination with glycerin, forming various compound ethers of rather complex constitution. The fatty acids which have been found in butter are butyric, caproic, caprylic, capric, myristic, palmitic, stearic, and oleic acids.

In speaking of these acids it is usual to describe the first four as soluble, as they are more or less soluble in hot water, whilst the remaining four are called insoluble, as they are insoluble in boiling water. The first group may be further divided into soluble and insoluble in cold water, and the second group into those in which the lead salts are soluble or insoluble in ether.

Three radicals of these acids are combined with one molecule of glycerin to form a molecule of butter fat. As butter fat contains several members of the fatty acid series it is not unreasonable to expect that in the same molecule there would be found, not three combining quantities of the same acid, but possibly three different acids, forming a tri-acid compound as follows:

Oleic acid
Palmitic acid } Glycerin.
Butyric acid

The results of an investigation into the character of butter fat indicate that its composition is in agreement with this theory. When ordinary animal fat is melted and mixed, say with 10 per

cent. of butyrin, or tri-butyrate of glycerin $(C_4H_7O)_3C_3H_5O_3$, the latter compound is entirely removed by treatment with warm alcohol, and the animal fat is recovered in practically the same condition as before the admixture.

When, however, butter fat is treated with hot alcohol, from 2 to 3 per cent. only of its weight is dissolved. This does not consist, as might be supposed, of compounds of glycerin with butyric and caproic acids, but of a fat which is liquid at 60° F. (15·5° C.), and yields on saponification from 13 to 14 per cent. of soluble fatty acids, and from 79 to 80 per cent. of insoluble fatty acids. The low melting-point of the extracted fat does not arise from an increased proportion of oleic acid, as the insoluble acids obtained after saponification have a higher melting-point than the mixed insoluble acids obtained from the butter fat. These results closely agree with a compound of the following composition:

$$\left.\begin{matrix} C_{18}H_{33}O \\ C_{16}H_{31}O \\ C_4H_7O \end{matrix}\right\} C_3H_5O_3.$$

that is oleo-palmito-butyrate of glycerin.

The results of the partial saponification of butter fat tend to confirm this theory of the complex character of its composition; but, before describing the experiments made in this direction, it may be useful to point out briefly what occurs when a butter is saponified, or converted into a soap.

When melted butter fat is placed in contact with an alcoholic solution of soda or potash, and gently heated, it is split up into glycerin, which is set free, and fatty acids, which combine with the alkali to form a soap. On the addition of a sufficient quantity of a mineral acid, such as sulphuric acid, to the soap dissolved in an excess of hot water, the fatty acids are set free, those soluble in hot water remaining in solution, and those insoluble rising to the surface in the form of an oil.

When a quantity of butter fat is treated with an alcoholic solu-

tion of alkali in quantity insufficient to combine with the whole of the acids in the portion operated on, the alkali, as might be expected in the case of a compound built up, like butter, with two or more acid radicals in the same molecule, combines with the more soluble acids, and leaves a compound of glycerin entirely deprived of its soluble acid.

In illustration of this it may be useful to give the results of an actual experiment. Twenty grams of butter fat, rich in soluble acids, were treated with half its equivalent of soda dissolved in alcohol. The mixture was warmed, and at the point of complete solution of the fat an excess of hot water was added, which threw out of solution a quantity of unsaponified fat. This was drawn off, washed with hot water, and dried in a water-bath. An oil was obtained which solidified at about 40° F. (4·4° C.), and, on being saponified with a standard solution of soda, yielded no soluble acids, but 88·1 per cent. of insoluble fatty acids. This result agrees closely with the composition of a di-acid glyceride, such as oleo-palmitate of glycerin, thus:

$$\left.\begin{matrix} C_{18}H_{33}O \\ C_{16}H_{31}O \\ HO \end{matrix}\right\} C_3H_5O_3.$$

When an attempt is made to fractionally separate the various glycerides by solution and precipitation in mixtures of ether and alcohol, the several parts, as already indicated, remain essentially of the character of a butter, with the exception of a small proportion of a hard crystalline fat. This is equal to about 2 per cent. of the butter fat used, and is soluble in warm ether, and gives on saponification only one-half per cent. of soluble fatty acids.

The following are the results of a proximate analysis of a superior English butter, showing the fat, curd, salt, and water:

Fat	90·27
Curd	1·15
Salt	1·03
Water...	7·55
	100·00

Fat.—The amount of butter fat in butter—that is, the portion left after separation of all the water, salt, and curd—ranges from 78 to 90 per cent., the average being about 82 per cent.

Water.—Butter contains a variable quantity of water, derived from the cream or milk used in its production and from the water employed in washing out the excess of curd from the newly aggregated butter. The proportion of water in commercial butters ranges from 5 to 20 per cent., but the great bulk of samples give from 8 to 16 per cent. A greater amount of water in butter than 12 per cent. is unnecessary, so far as attaining a good appearance is concerned, and anything over 16 per cent. is injurious to the keeping qualities of the butter. It is stated that in some dairy districts it is not unusual to systematically work in a quantity of water in addition to that which naturally becomes enclosed in the butter in the ordinary process of manufacture; and this practice, which answers no purpose except that of adding weight to the butter, is one to be greatly deprecated.

Curd.—Butter contains, relatively, only a small percentage of curd, derived from a portion of the milk being enclosed in the fat at the time of its separation during the process of churning. It consists almost entirely of casein with a little milk-sugar and lactic acid.

The presence of an undue quantity of casein, which is an albuminous substance liable to decomposition, has the effect—especially when little salt and much water are present—of producing a very rapid change in the flavour and quality of the butter. It soon becomes rancid from the liberation of butyric and other acids, and its sweet and agreeable flavour gives place to a cheesy one. Although it has not been ascertained with any degree of precision to what constituents the distinctive flavour of butter is due, it is well known that it is rapidly altered when the curd begins to decompose. The mould or fungus which develops during this

change, appears to feed partly upon the glycerin which is liberated from the butter fat, and of which no traces are found in the free state in old butters containing a considerable proportion of free fatty acids.

Apart from the use of sweet cream or milk, the art of making butter which shall preserve its delicate aroma and taste, chiefly consists in the removal, by repeated treatment with spring water, of excess of curd, and also of the whey, or watery portion of the milk, which always contains sugar.

When the cream is held over for several days until it has become sour and is then churned, the butter produced is not only often inferior in flavour, but soon undergoes further deterioration.

We have found in butters from ·11 to 5·3 per cent. of curd, but the larger proportion contained from ·5 to 2 per cent. If butter is carefully prepared, the amount of curd should not exceed 1 per cent.

Salt.—Butter contains very variable quantities of salt. We have found the salt to vary from ·4 to 15 per cent.; the majority of samples, however, yielded from 2 to 7 per cent.

There exists no clear distinction between salt and fresh butters, as the degree of saltness which would be allowed in a fresh butter according to the custom of one part of the country might be so great as to constitute a salt butter in another district.

Fatty Acids.—When butter fat is saponified, water combines with some of the constituents, and the weight of the whole is proportionately increased. Thus, in the saponification of the butter fat referred to above, 100 parts of it became converted into 106·32 parts of glycerin and fatty acids. The following are the results of an analysis of this fat:

Butyric acid	6·13
Caproic, caprylic, and capric acids . .	2·09
Palmitic, stearic, and myristic acids . .	49·46
Oleic acid	36·10
Glycerin	12·54
	106·32

The amount of butyric acid may be ascertained by decomposing the butter soap with normal sulphuric acid in the manner described on page 55; but instead of filtering the hot solution, the contents of the flask are cooled below 60° F. (15·5° C.), and the acid solution is passed through a filter. The solidified fatty acids are heated with hot water and again cooled, and the aqueous solution filtered and added to the former filtrate. The free acid in the filtrates is estimated by neutralizing with decinormal soda solution, and from the number of cubic centimetres used the percentage of acid is calculated—88 being taken as the equivalent of butyric acid.

The proportion of caproic and other fatty acids of this group which are insoluble in cold water, and which remain in the solid condition in the flask, is determined by washing out these acids with hot water from the insoluble fatty acids, neutralizing the acid filtrate with baryta water, evaporating to dryness, and weighing the barium salt. This may now be ignited, and the weight of the combined acids calculated from the amount of carbonate of barium left on ignition; or the carbonate of barium may be converted into sulphate, and the weight of barium combined with the fatty acid salt estimated therefrom. The equivalent of these acids in the butter fat—the analysis of which is given above—was 136, which shows that the proportion of soluble acids is under-estimated when calculated, as is usual in butter analysis, from the atomic weight of butyric acid.

The percentage of oleic acid may be obtained by converting the insoluble fatty acids into a lead soap, extracting the oleate of lead with ether, and decomposing the ethereal solution of the soap with hydrochloric acid. The solution which contains the oleic acid is filtered, the ether evaporated off, and the oily residue —oleic acid—weighed.

The palmitic acid, etc., may be estimated by difference; the percentage of oleic acid found being deducted from the total percentage of insoluble fatty acids.

The proportions in which the acids which are soluble and insoluble exist in butter are variously stated by different chemists. The want of agreement in results arises, not from any material difference in the methods of analysis, but from the fact that such an article as butter, derived as it is from different breeds of cows, and under the varying conditions of food and climate, is liable to considerable difference in composition, especially in respect to the proportion in which the more soluble acids are present. This fact will be seen in the table of the results of the analysis of over one hundred samples given on pages 64–66.

The following is a brief description of the fatty acids in butter:

Butyric Acid, $C_4H_8O_2$.—This acid occurs as a glyceride in various animal and vegetable fats, but it exists most abundantly in butter fat. It also occurs in human perspiration and in various kinds of decomposing vegetable and animal matter, and it exists as a compound ether in the oil of *Heracleum giganteum*, and also in the oil of the seeds of the common parsnip. It is produced by the oxidation of normal butyl alcohol, and there are other ways in which it may be prepared; but the most convenient method of preparation is by the fermentation of sugar in contact with putrid cheese.

Butyric acid is a colourless liquid possessing a rancid odour; its specific gravity is 0·958 at 57·2° F. (14° C.), and it may be distilled unchanged. It is soluble in all proportions in alcohol, ether, and cold water, but it is readily thrown out of solution by the addition of soluble salts.

Caproic Acid, $C_6H_{12}O_2$.—This acid, besides being present in butter fat, occurs in considerable quantity in cocoa-nut oil, and exists, like butyric acid, in a free state in perspiration. It also occurs as a compound ether in the volatile oil of cow-parsnip (*Heracleum spondylium*). It is produced by the oxidation of albuminous substances, and also of the fatty acids of higher atomic weight.

Caproic acid is a colourless mobile oil, soluble in alcohol ether, and boiling water; it has a specific gravity of 0·931 at 59° F. (15° C.); boils about 401° F. (205° C.), and possesses a somewhat pleasant but pungent odour.

Caprylic Acid, $C_8H_{16}O_2$.—This acid, besides occurring in butter, forms one of the constituents of cocoa-nut oil, and it is also found in several kinds of fusel oil, partly free and partly combined with ethyl and amyl. It dissolves readily in alcohol and benzol; is insoluble in cold water, and but slightly soluble in hot water.

Caprylic acid has a specific gravity of ·911 at 68° F. (20° C.); boils at 456·8° F. (236° C.), solidifies at 53·6° F. (12° C.), and possesses a faint but unpleasant odour, particularly when warmed.

Capric Acid, $C_{10}H_{20}O_2$.—This is a white crystalline body, possessing a faint odour of the goat. Besides being present in butter, it is associated with caproic and caprylic acids in cocoa-nut oil. It also forms a constituent of fusel oil, and especially of that produced in the distillation of grain spirit.

Capric acid is very soluble in alcohol and ether, insoluble in cold water, but slightly soluble in boiling water. It melts about 81° F. (27·2° C.).

Myristic Acid, $C_{14}H_{28}O_2$.—The proportion of this fatty acid in butter is small. It forms a constituent of several vegetable fats, such as nutmeg butter, Otoba wax, cocoa-nut and croton oils, and Dika fat. It is said to amount to more than one-half of the fatty acids contained in the latter.

Myristic acid is a solid body, forming white crystalline laminæ resembling palmitic acid. It is insoluble in water and ether, but is readily dissolved by hot alcohol, from which it crystallizes on cooling. It melts at 128·8° F. (53·8° C.), and is of a less specific gravity than water.

Palmitic Acid, $C_{16}H_{32}O_2$.—This acid forms a large proportion of the insoluble fatty acids of butter fat. It occurs as a glyceride

in many natural fats, such as palm oil, the produce of *Elæis guineensis*; Chinese tallow, the produce of the tallow-tree, (*Stillingia sebifera*); and in Japan wax, from *Rhus succedanea.*

Palmitic acid is a white solid, without odour or taste. It is lighter than and insoluble in water, but is readily dissolved by hot alcohol or ether, and melts at 143·6° F. (62° C.), and on cooling solidifies to a horny laminated mass.

Stearic Acid, $C_{18}H_{36}O_2$.—This is not present in large quantity in butter fat. It forms a constant constituent of the solid fats of the animal kingdom, and is most abundant in beef and mutton suet. It is a white solid without smell, is insoluble in water, but soluble in alcohol and ether. It melts at 156·2° F. (69° C.), and on cooling solidifies like palmitic acid to a horny laminated mass.

Oleic Acid, $C_{18}H_{34}O_2$. — This acid, which belongs to the acrylic series of acids, forms about a third of the weight of the whole butter fat. It is widely distributed, constituting the fluid portion of most natural fats and fixed oils—such as olive and almond oils.

Oleic acid is tasteless and inodorous, and has a specific gravity of 0·898 at 66·2° F. (19° C.). It is insoluble in water, very soluble in alcohol, and dissolves in all proportions in ether. It crystallizes from alcoholic solution in white needles, which melt at 57·2° F. (14° C.) to a colourless oil. It solidifies at 39·2° F. (4° C.).

MICROSCOPIC APPEARANCE.

It may be of some interest to give the microscopic appearance of genuine butter, although in practice the microscope is very little resorted to in the examination of suspected samples, except for the detection of mechanical impurities. It will be seen from the figure below that butter consists of a mass of minute globules of fat, each being distinct. A few globules of a larger size are seen scattered irregularly over the field.

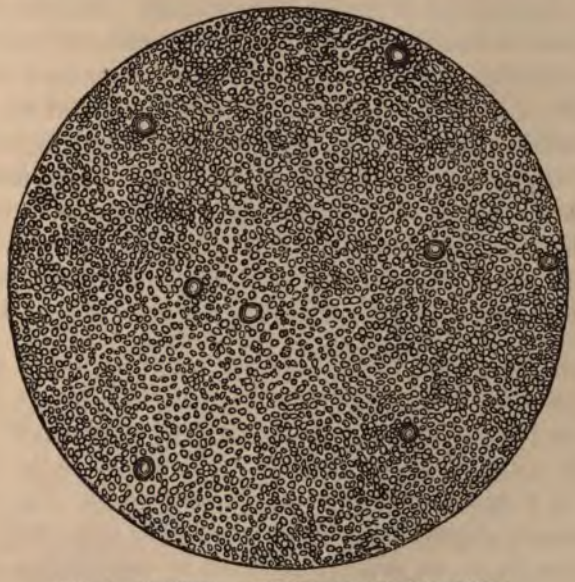

FIG. I.—BUTTER. MAGNIFIED 350 DIAMETERS.

ANALYSIS.

The analysis of butter divides itself into two parts: 1st. The estimation of the water, salt, curd, and fat; and 2nd. The determination of the composition of the butter fat.

Water.—The water is estimated by drying a portion of the butter in a platinum dish at a temperature of 212° F. (100° C.). It has been recommended to dry at a few degrees higher than 212° F.; but we have found the latter temperature to give perfectly satisfactory results when the evaporation is carefully conducted. Five grams of butter, taken from the sample at a part towards the middle, or where a true average can best be obtained, are weighed in a platinum dish of such a shape as will allow the butter to form as thin a layer as possible at the bottom. The tare of the platinum vessel, which should contain a glass rod with a flattened end, is previously ascertained. The platinum is now placed in one of the holes of an open water-bath kept in a state of ebullition, and the butter well stirred from time to time in order to distribute the water through the melted fat. The evaporation of the water proceeds with great regularity, and the lowest weight is attained in three or four hours. As the tendency of heated fat is to increase in weight after a time, it is very desirable that the drying should be conducted with as much despatch as possible. The loss of weight is ascertained and reckoned as water, and the percentage calculated therefrom.

Salt.—The dried butter from the last experiment is treated with warm ether or petroleum spirit, and the contents of the platinum vessel poured on to a tared filter and washed with ether until all traces of fat are removed. The residue on the filter is dried in a water-bath and its weight ascertained. The salt is subsequently dissolved out by treatment with warm water, and the chlorides in the solution estimated by precipitation with a solution of nitrate of silver, or by titration with a decinormal solution of that salt. The quantity of chlorine found is resolved into its equivalent of chloride of sodium, or common salt, from which the percentage of salt in the butter is calculated.

Curd.—The difference between the weight of salt ascertained, and the total weight of curd and salt found on the tared filter, is

regarded as the amount of curd present. It may be also determined by weighing the dried residue on the tared filter after removal of the salt. This usually gives from four to five tenths per cent. less curd, owing to the more soluble portions of it having been dissolved out in the warm water.

Fat.—The butter fat can be estimated by evaporating the ether filtrate from the salt, etc., drying and weighing the residue of fat. As butter fat, however, is liable to somewhat increase in weight by this treatment, it is more accurate to determine the fat by deducting the water, curd, and salt from the weight of butter operated upon, and calculating the percentage of fat from the remainder.

In the analysis of butter fat the principal object is to ascertain the relative proportion of those compounds which are distinctive of butter and the compounds which are common to ordinary animal and vegetable fats. A secondary interest attaches to the proportion in which these exist among themselves; but as, with the exception of butyric and oleic acids, there are no definite methods of quantitatively estimating the fatty acids with any degree of accuracy, their further separation is seldom resorted to.

The amount of soluble and insoluble fatty acids may be determined by the saponification of a portion of the butter fat. To do this the fat is first separated from the water, curd, and salt, by heating the butter in a glass beaker in a water-bath at about 150° F. (65·5 C.), decanting the clear separated fat, which is passed through a filter to remove any particles of curd or salt which it may contain. The separation of the fat should be conducted as quickly and at as low a temperature as possible. The specific gravity of the perfectly clear and dry fat is then taken at a temperature of 100° F. (37·7 C.).

For this purpose an ordinary specific gravity bottle of a pear-shape is used, into which a sensitive thermometer is inserted, the bulb of which extends nearly the whole depth of the bottle.

The fat is introduced into the bottle about 15° above the standard temperature, and gradually brought down to that point, when the bottle should be quickly filled from the residue of the fat, also cooled to the temperature of 100° F. (37·7° C.), care being taken to push the glass stopper home, otherwise an excessive gravity will be obtained.

It has been recommended to adjust the temperature of the fat in the bottle by placing it in water kept at 100° F.; but we have found this an unnecessary precaution, as, where the requisite care is taken, the first mode gives perfectly reliable results.

To obtain the true specific gravity of the fat the weight obtained must be divided by the weight of water, at 100° F., which the same bottle will contain, and multiplied by 1000.

If, for instance, a bottle were used which contained 50 grams of distilled water at 100° F. (37·7° C.), and the weight of fat at the same temperature was found to be 45·58 grams, then the specific gravity of the fat would be $(\frac{45\cdot58}{50} \times 1000)$ 911·6, water being 1000. The temperature of 100° F. has been selected because nearly all mixtures of animal or vegetable fats which might be used to adulterate butter do not solidify until they fall a few degrees below that temperature.

In applying the saponification test a solution of soda of indefinite or of known strength may be used according to whether only the insoluble acids or the acids of both kinds are sought to be known. The former method was first applied by Hehner and Angell, in the analysis of butter; but an improvement in the process, which enabled both descriptions of acids to be ascertained, was suggested by Dupré.

For this purpose two solutions are prepared, one a normal alcoholic solution of soda, and the other a solution of sulphuric acid, slightly stronger than the soda solution. An assay flask of stout glass, tightly fitted with a cork or india-rubber stopper, is selected. A quantity of dry melted butter fat, from 4 to 5 grams, is placed in the flask, and 25 cubic centimetres of the norma

solution of soda are added, the cork tied down with a piece of leather or canvas, and the flask placed over a water-oven for one hour, the contents being gently shaken from time to time with a circular motion.

The flask is now removed, and allowed to stand till nearly cold, and the soap solution washed with hot water into a larger flask, measuring about 200 cubic centimetres, and having a short wide neck.

The flask is placed on a water-bath for an hour, or until most of the alcohol has evaporated, and the soap is then, while quite hot, decomposed by the addition of 25 cubic centimetres of the sulphuric acid solution. At the same time 25 cubic centimetres of the sulphuric acid solution are added to 25 cubic centimetres of the soda solution, and the excess of acid ascertained by neutralizing the mixture with a decinormal solution of soda, and a note made of the number of cubic centimetres required for this purpose. The insoluble fatty acids rise to the surface; but it is generally necessary to shake the contents occasionally, to bring the fats into the form of an oil, before proceeding to separate them from the other fatty acids.

A Swedish filter paper of the best quality is dried and carefully tared, placed in a glass funnel, and thoroughly wetted with boiling water. The contents of the flask are transferred to the filter, and the flask repeatedly washed with hot water, until all traces of fat are removed to the filter. The filter paper and fat are also well washed, until the filtrate ceases to be sensibly acid to test paper, which usually takes place when from 600 to 700 cubic centimetres of filtrate have been obtained. The filter, and fat when sufficiently cool, are removed to a tared platinum dish, dried in a water-bath at 212° F. (100° C.), and weighed. The weight, less the tares of the filter and platinum dish, gives the amount of insoluble fatty acids.

If the fat appears to have been imperfectly removed from the flask it is desirable, as a precaution, to wash out the flask with

a little ether, and evaporate in a separate vessel. It is seldom that more than mere traces of fat are found by this treatment.

The filtered solution containing the soluble fatty acids is titrated with the decinormal soda solution. The number of cubic centimetres required, less the number of cubic centimetres which the sulphuric acid solution exceeds the soda as noted above, represents the free acids derived from the butter. It has been found convenient to calculate these as butyric acid ($C_4H_8O_2$). In an experiment in which five grams of butter were used, and the excess acidity of the sulphuric acid solution was 4·5 cubic centimetres, and the total acidity 37·5 cubic centimetres of decinormal soda, then, as ·0088 gram is the butyric acid equivalent of 1 cubic centimetre of soda solution $(37{\cdot}5 - 4{\cdot}5) \times {\cdot}0088 \times 100 \div 5 = 5{\cdot}80$ per cent. as butyric acid.

Muter has recommended the separation of the acids in the cold. The soap is decomposed as in the former experiment—the fats allowed to separate and the flask placed in cold water. The crust of fat is then broken, and the solution poured through muslin; the fats are again dissolved in hot water, cooled, and poured off as before, and the process repeated a third time. Any portion of the solid fat which may have been poured off is returned to the flask, and the fat dried in an air bath a few degrees above 212° F. (100° C.).

The soluble acids in the filtrate are estimated in the same way as above described. This method would give too low a percentage of soluble acids in a butter containing any appreciable quantity of caproic or caprylic acid, both of which are nearly insoluble in cold water.

The oleic acid in the insoluble acids may be estimated by converting them into a lead soap by heating with finely divided lead oxide. The soap is repeatedly digested with warm ether to dissolve out the oleate of lead. To the filtrate is added dilute hydrochloric acid to decompose the soap; and the solution which contains the liberated oleic acid is filtered from the

chloride of lead, evaporated, and the acid weighed in a tared beaker.

The separation of the stearic, palmitic acids, etc., is attended with great difficulty; but by means of fractional precipitation with acetate of magnesia and repeated crystallization from alcohol, they may be separated in such a state of purity as to enable the particular acid to be identified. The process given by Heintz, and which we have successfully applied for the identification of stearic acid in butter, may be stated as an example of the method to be adopted for the separation of the several fatty acids. The butter is dissolved in as small a quantity of warm ether as possible, and the more solid fats allowed to crystallize. The solid portion is pressed between bibulous paper, and again dissolved in ether; and the process of crystallization and solution several times repeated until a fat melting between 136° F. (57·7° C.) and 140° F. (60° C.) is obtained. Four parts of this fat are dissolved in such a quantity of hot alcohol that no part of the fat will crystallize out on cooling. To the alcoholic solution one part of acetate of magnesia dissolved in warm alcohol is added, and left to crystallize. This is separated and pressed between bibulous paper, and finally decomposed by heating with dilute hydrochloric acid. The fat is now crystallized once or twice from alcohol, pressing the crystalline precipitate each time, or until a fat melting at 154° F. (67·7° C.) is obtained. It is essential that the fat should be crystallized from alcohol after precipitation by acetate of magnesia, otherwise there is danger of obtaining a compound melting at 147° F. (63·9° C.), the fusing point of palmitic acid, for which it is liable to be mistaken, though really containing seven parts of stearic to three parts of palmitic acid.

Melting-point.—Various methods have been suggested for determining the melting-point of butter fat, but, in the course of our experience, we have found that uniform results can be best obtained if the butter fat be first suddenly cooled by floating the

platinum capsule containing it in ice water. A small portion of the fat, which has then a somewhat vitreous appearance, is taken up on the loop of a platinum wire and introduced, close to the bulb of a thermometer, into a beaker of water set in a porcelain dish also containing water. The heat of the water is then slowly raised, and the temperature read off immediately the fat assumes the liquid condition.

ADULTERATION.

When butter is adulterated it is usually with an excess of water or salt, or with an admixture of ordinary fats of animal or vegetable origin. It is very rarely, if at all, that such substances as flour or mineral matter are at the present time added to butter. The principal task now left to the analyst in connection with butter analysis is to determine the presence and proportion of added fat in samples of butter which are reputed genuine.

The methods of arriving at these results were at one time of a crude and very unsatisfactory kind, but these now possess scarcely an historical interest. The discovery of the tests described on a previous page, which are readily applied and uniform in their results, has, however, brought the methods of analysis of butter to be, at least, on a par with those employed in the examination of most other natural products. The work of the analyst is often much simplified by finding that the sample consists almost entirely of ordinary animal and vegetable fats, which have been worked up into the appearance of butter by agitation with milk and colouring matter, and subsequently seasoned with salt. The preparation of an article of this kind, and which has for some time been well known under the names of "oleo-margarine" and "butterine," has developed into a very considerable industry in America and on the Continent, and recently to a more moderate extent in this country. The following is a brief description of the method

practised in the United States in the making of this compound. Carefully selected ox fat, which has been freed from all unsightly pieces, is soaked first in warm and afterwards in cold water, and when the water has been drained off, the fat is finely divided by means of a "hasher," introduced into the melting-pan and heated by a steam coil to a temperature of 120° F. (48° 8′ C.). The clear fat is then drawn off and allowed to cool slowly to a temperature of 70° F. (21·1° C.), at which it should remain from twelve to twenty-four hours, until distinct granulation has set in. The semi-solid fat is afterwards enclosed in cloths and submitted to high pressure, and the extracted oil collected in suitable vessels. The proportion of oil obtained is nearly 50 per cent. of the quantity of fat operated upon. The hard and stearine-like pieces of fat remaining in the press are removed and disposed of for other purposes. The oil, at a temperature of 70° F. (21·1° C.), is churned up with milk and a small proportion of annatto and carbonate of soda, and the product conveyed into a tub containing powdered ice. The object of suddenly cooling the fat is to prevent the formation of "grain" and produce the article in a soft condition similar to that which is characteristic of butter. After the ice has melted, and the excess of water has been drained off, the mass is again churned with sour milk, and salt is afterwards added to the extent of from 4 to 6 per cent. The product is then packed in firkins and made ready for the market. Some of the "oil" is exported to Europe, where it is used either for mixing with genuine butter, or for making "butterine" after the method employed in America.

The process as conducted in this country differs from the one described in, at least, one important particular. Ox fat, from which everything that is discoloured has been removed, is heated to a temperature of about 120° F. (48·8° C.) A clear sweet-flavoured fat is obtained, which is subsequently mixed with a certain proportion of pure vegetable oil, such as nut or olive oil. The mixture, which melts at a lower temperature than butter fat, is

cooled quickly, so as to prevent granulation as much as possible. It is then churned up with new milk, and subsequently salted and packed in kegs for sale under the name of "butterine."

A preparation of this kind, when made from perfectly wholesome fat, forms a useful article of food where a low-priced substitute for butter is demanded, as must be the case among the poor, to whom really good fresh butter may be regarded as a luxury. Apart, however, from the deficiency in flavour, it is doubtful whether "butterine" can be said to fully supply the place of butter as an article of diet. When the highly complex and peculiar character of the constitution of butter is considered, and that it is the fat derived from or natural to milk which for a time at least is the principal food of the young, it is probable that butter performs some more specific office in the system than ordinary fats.

When "butterine" is sold under its proper name there can be no objection to its sale, but when sold as butter, or mixed with it, the sale of the spurious article becomes a manifest fraud. In the detection of foreign fats advantage is taken of the difference between butter fat and ordinary animal or vegetable fats in specific gravity, in the proportion of soluble and insoluble acids which they yield, and in their melting-points. The specific gravity test has been, after a lengthened trial, found to be thoroughly reliable, no sample of genuine or factitious butter having been met with in which the character of the fat was not as correctly indicated by the specific gravity as by the determination of the fatty acids. Though it is well known that fats when strongly heated increase in gravity, yet, when the low temperature at which the fats are prepared for mixing with butter is taken into account, and which appears to be essential to the preserving of their sweet flavour, it is evident that in the manufacture of spurious butter there would be no such increase in the gravity of the animal or vegetable fats as would materially interfere with the test. The indication given by the specific

gravity of the fat may be confirmed by the estimation of the fatty acids, as described under the head of "Analysis." In instances where it is not thought necessary to estimate both the soluble and the insoluble acids, the determination of the former is to be preferred, because the results can be obtained with greater precision and despatch, and in the estimation of the insoluble acids the drying is attended with some uncertainty and loss of time.

In the course of an investigation into the variations in the composition of butter we have analysed a large number of genuine samples, which were selected so as to obtain as far as possible fair representative specimens of butter produced under different conditions, and the results are given in the following table:

TABLE I.—*continued.*

No.	Percentage of				Butter Fat.		
	Water.	Salt.	Curd.	Butter Fat.	Specific Gravity at 100° Fahrenheit.	Melting-point Fahrenheit.	Percentage of Fixed Fatty Acids.
						°	
76	11·74	1·32	·42	86·52	911·68	90	—
77	8·72	·58	·70	90·00	912·18	88·5	—
78	9·55	4·17	·24	86·04	911·98	88·7	—
79	9·60	6·45	·82	83·13	912·28	89	—
80	14·36	2·66	1·46	81·52	912·99	88·5	—
81	17·56	2·98	1·14	78·32	912·39	89	—
82	17·18	3·00	1·24	78·58	912·99	88·5	—
83	18·72	2·24	1·36	77·68	912·39	89	—
84	13·14	5·74	2·96	78·16	913·97	88	—
85	19·40	3·70	·56	76·34	912·96	89	—
86	13·70	2·30	1·86	82·14	912·28	90	—
87	15·94	2·40	2·68	78·98	911·06	91·5	—
88	18·52	4·84	2·16	74·48	911·91	90·5	—
89	14·90	6·04	1·50	77·56	911·88	90·5	—
90	14·98	3·74	1·14	80·14	910·97	91·5	—
91	11·71	3·04	·76	84·49	913·14	88·5	—
92	13·51	2·90	·70	82·89	913·09	88·5	—
93	17·60	2·60	·98	78·82	910·63	93	—
94	14·60	—	—	—	912·23	89	—
95	15·34	·40	·69	83·57	910·62	91	—
96	14·64	·46	·82	84·08	910·41	91·5	—
97	10·43	2·46	·57	86·54	911·48	89	—
98	11·05	7·71	·44	80·80	910·73	93	—
99	13·21	1·74	·56	84·49	911·79	90·5	—
100	11·99	2·23	·99	84·79	911·82	89	—
101	13·39	6·68	1·62	78·31	910·42	92·5	—
102	13·59	15·08	1·36	69·97	909·47	93·5	—
103	13·50	2·58	·55	83·37	911·04	91·5	—
104	14·55	5·86	1·31	78·28	910·30	93	—
105	12·43	3·55	·55	83·47	910·70	92	—
106	14·34	3·31	·78	81·57	911·88	90·5	—
107	12·55	2·22	1·35	83·88	912·20	91·5	—
108	13·11	1·66	·46	84·77	911·78	91·5	—
109	12·79	1·03	·66	85·52	910·11	93	—
110	12·36	3·24	·87	83·53	910·11	93	—
111	11·02	1·89	·87	86·22	911·76	91	—
112	14·12	2·28	1·06	82·54	912·80	90	—
113	15·70	1·54	1·49	81·27	911·78	92	—

It will be seen that the percentage of fixed fatty acids was only determined in about half the number of the above samples, but the number is sufficient to show the correspondence between these acids and the specific gravity of the fat, and that it is possible to predicate within a few tenths one result from the determination of the other.

It is a noticeable feature in the results that while a few samples were very poor in quality and a few others exceptionally rich, the great majority of the butters were found to possess considerable uniformity of composition. Some of the poorest butters were produced by and obtained from small farmers at a time when food was scarce. It was also noticed during the investigation that butter is relatively poorer in its essential constituents when the food of the cows consists chiefly of cotton and oil cake than when roots and grass form their staple food.

The great variation in the quantity of water in the different butters is a notable feature in the results recorded in the foregoing table; and it is remarkable that the Devon and Dorset butters, which usually stand so high in the market, contained in nearly all cases a large quantity of water, the amount varying from 13·22 to 18·72 per cent. Number 62, which was procured from the dairy of a private gentleman in Cornwall, contained as much as 16·99 per cent.; and a second sample subsequently obtained from the same source contained 15·70 per cent.; thus showing that the large quantity of water present was due to the mode of manufacture, rather than to an attempt to load the butter with an undue proportion of water.

These percentages of water are doubtless unnecessarily high, and likely to interfere with the keeping properties of the butter, but when such quantities are found in well-made butter of private dairies, it is difficult to maintain that similar percentages in butter for sale amount practically to an adulteration with water.

The following table, in which the proportion of insoluble and

soluble acids is shown, exhibits nearly the extreme variations which occur in these acids, and which are likely to be found in genuine butters. The average proportion of soluble fatty acids appears to lie between 5 and 6 per cent.; but the percentage not unfrequently falls as low as 4·5, and the percentage of insoluble acids sometimes slightly exceeds 89·0. In imperfectly prepared or long-kept butter the soluble acids may be found a few tenths below 4·5, and the insoluble acids higher than 89·0 per cent., as will be seen in the case of Nos. 50 and 51, Table I.

TABLE II.—ANALYSES OF TEN REPRESENTATIVE SAMPLES, SHOWING THE ORDINARY VARIATIONS IN THE COMPOSITION OF BUTTER FAT.

No.	Percentage.				Butter Fat.			
	Water.	Salt.	Curd.	Butter Fat.	Specific Gravity at 100° F.	Per cent. Fixed Acids.	Per cent. Soluble Acids as Butyric Acid.	Melting-point Fahrenheit.
								°
1	7·55	1·03	1·15	90·27	913·89	85·56	7·41	85
2	11·71	3·60	·95	83·74	911·45	88·24	5·41	90
3	16·89	8·56	1·23	73·32	911·48	88·82	4·64	89·5
4	16·28	3·32	1·56	78·84	912·79	86·00	7·00	88·5
5	11·42	1·29	1·12	86·17	910·47	88·53	4·84	90
6	12·55	·89	·74	85·82	910·20	89·00	4·57	90
7	12·96	2·43	1·25	83·36	912·51	88·25	5·45	89
8	13·40	1·39	2·03	83·18	911·67	88·72	5·07	90
9	12·05	0·96	1·95	85·04	911·04	87·51	5·28	88
10	14·62	1·48	1·88	82·02	910·70	89·00	4·50	91

The following table shows the specific gravity of ordinary animal fats at 100° F. (37·7° C.), and also the percentage of fixed fatty acids contained in each.

TABLE III.—ANALYSES OF ANIMAL FATS.

Description of Sample.	Specific Gravity at 100° F.	Percentages of Fixed Fatty Acids.
Mutton Suet...	902·83	95·56
Beef Suet	903·72	95·91
Fine Lard	903·84	96·20
Dripping (commercial)	904·56	94·67
Mutton Dripping (genuine)	903·97	95·48

It will be seen that the specific gravity of the above samples of ordinary animal fats varies from 902·83 to 903·84, while the specific gravity of butter fat, as exhibited in Tables I. and II., rarely falls below 910·, the usual range being from about 911· to 913·. There is thus a material difference between the specific gravity of butter fat and that of ordinary commercial animal fats, and there is a corresponding difference between the percentage of fixed fatty acids in the latter, and the proportion of the like acids contained in butter fat, and these respective differences become immediately available, not only as a test for determining the purity of butter, but for estimating the proportion of foreign fat present. The two samples of dripping had a slightly higher specific gravity than the animal fats, doubtless due in the genuine sample to the action of heat during the roasting of the meat, and in the commercial sample probably partly also due to the use of butter in that process.

In the following table will be found the results of the analyses of five samples of butterine or oleomargarine butter met with in commerce, all having been sold as butter.

TABLE IV.—ANALYSES OF SAMPLES OF OLEOMARGARINE BUTTER OR BUTTERINE.

Percentage of				Fat.			
Water.	Salt.	Curd.	Fat.	Specific Gravity at 100° F.	Percentage of Fixed Acids.	Percentage of Soluble Acids.	Melting-point Fahrenheit.
							°
14·30	3·81	0·48	81·41	903·84	94·34	—	82
11·21	1·70	1·73	85·36	902·34	94·83	·66	78
12·33	4·00	1·09	82·58	903·15	95·04	·47	79
5·32	1·09	·67	92·92	903·79	96·29	·23	81
13·21	3·99	1·07	81·73	901·36	95·60	·16	78

These samples of spurious butter were all well prepared, and were undistinguishable in appearance from ordinary butter. The true character, however, of the article is at once revealed by the results of the analysis, as the specific gravity of the fat, and the percentage of fixed fatty acids, are almost identical in each case with the corresponding results of the analysis of an ordinary animal fat recorded in Table III.

When the data of an analysis of the fat of a suspected butter have been ascertained, the conclusion as to whether it contains foreign fat is arrived at by comparing the results with those given by undoubted butters and ordinary animal and vegetable fats. In the case of a butter giving the following results, the percentage of added fat would be indicated as follows:

Specific gravity of sample	906·6
Percentage of soluble acids	2·3
,, insoluble do.	92·4

Taking for comparison a genuine butter fat yielding low results—for instance, one giving

Specific gravity...	910·20
Percentage of soluble acids	4·60
,, insoluble do.	89·00

and an ordinary fat which, on the average, yields 96 per cent. insoluble acids, and has a specific gravity of 903·0; then calcu-

lating from gravity, we have $910{\cdot}2 - 903{\cdot} : 910{\cdot}2 - 906{\cdot}6 : : 100 : x = 50$ per cent.; and calculating from soluble acids, 4·6 per cent.: 2·3 per cent. : : 100 : $x = 50$ per cent. of added fat.

In drawing conclusions from the results of the analysis of a butter, regard should be had to the condition of the sample at the time of analysis. When butter is kept in small quantities in glass or earthenware vessels, it undergoes more or less deterioration. Whilst some of the finest and best-prepared butters undergo little or no change, there is in others a gradual disappearance of the characteristic principles of butter, and a consequent assimilation to the constitution of an ordinary animal fat. This change, which appears to be due to an incipient fermentation, and is generally accompanied by the development of fungi, is probably caused either by the use of sour cream, or by insufficient care in making the butter.

The following table exhibits the amount of depreciation which different samples of butter have undergone in the respective times stated:

TABLE V.—ANALYSES OF SAMPLES OF BUTTER AFTER KEEPING.

No.	Original Butter.		Time kept.	After keeping.	
	Spec. Grav. at 100° F.	Percentage of fixed fatty acids.		Spec. Grav. at 100° F.	Percentage of fixed fatty acids.
1	912·28	87·30	12 weeks.	910·74	88·97
2	911·58	87·80	7 ,,	909·19	90·00
3	913·89	85·50	7 ,,	913·57	85·72
4	911·78	87·40	6 ,,	911·00	87·97
5	911·06	87·72	8 ,,	910·61	88·40
6	911·48	87·65	6 ,,	911·33	88·00
7	912·39		12 ,,	911·28	
8	912·18		12 ,,	910·39	
9	912·28		12 ,,	911·24	
10	913·97		16 ,,	913·92	
11	910·19		8 ,,	908·15	
12	910·62		8 ,,	910·13	
13	911·04		6 ,,	910·75	
14	911·40		8 ,,	911·00	
15	910·70		5 ,,	910·57	

There is at least one natural fat, namely, cocoa-nut oil, though not likely to be used as an adulterant on account of its flavour, the presence of which could not be proved satisfactorily either by the specific gravity test or by the determination of the insoluble fatty acids, as the cocoa-nut oil in both these particulars gives nearly the same results as butter. This oil also contains nearly the same percentage of total soluble acids as butter fat, but differs in a marked degree in respect to the proportion in which these acids exist among themselves.

Whilst in butter we find that butyric acid greatly predominates, in the case of cocoa-nut oil the principal acids of this group are caproic and capric acids. These acids, especially the latter, are not so soluble in water as butyric acid, in the comparative absence of which they fail in the ordinary method of butter analysis to get washed out from the insoluble acids; so that the amount of soluble acids, partly for this reason, when reckoned as butyric acid, is only about one-fourth the percentage found in average butter fat. It follows, therefore, that the determination of the soluble acids affords a useful test in cases where cocoa-nut oil might be suspected.

Cocoa-nut oil, having a low melting-point, 73° F. (22·7° C.), any considerable admixture of this oil with butter would cause a reduction of the fusing-point of the mixture, and thus furnish additional evidence of its presence.

When fifty parts of butter fat melting at 91° F. (32·7° C.) are added to the same quantity of cocoa-nut oil melting at 73° F. (22·7° C.), the mixture fuses at a point intermediate to that given by the two fats, which is lower than could be obtained from a genuine butter. It is true that the melting-point might be raised by the addition of a more solid fat, but it is obvious that this would only defeat its own object by still further lessening the percentage of soluble acids.

As cases may occur where the melting-point is of much importance, this test is never overlooked in the analysis of a

reputed butter. The method which we adopt in determining the melting-point of butter fat is described on page 59.

Salt.—The proportion of salt found in butter rises to 15 per cent. in the Table of Analyses cited; but leaving out this instance as an unusual amount, it will be observed that several samples contain nearly 9 per cent. It would therefore appear that 8 or 9 per cent. is not objectionable to the public taste; and as consumers of butter soon discover when the amount of salt is excessive, the degree of admixture is one which they are very likely to regulate for themselves.

The presence of flour or starchy substances in butter could be easily detected by the microscope, and the addition of any insoluble mineral matter, such as soapstone, which has been alleged to have been found in butter, would, without fail, be detected in the non-fatty portion of the butter after dissolving out the salt and igniting the residue.

It is very unlikely that such a clumsy method of adulteration will now be adopted, seeing that there exists such an efficient and cheap substitute for butter as "butterine," and which can be so readily procured by anyone desirous of practising sophistication.

MICROSCOPIC EXAMINATION.

At one time fat prepared for making spurious butter was almost invariably found to possess a crystalline structure, and whether in a separate form, or when mixed with genuine butter, there was no difficulty in detecting the crystals by the microscope, and such evidence raised a presumption of the presence of foreign fat. Now, however, the fat is generally so suddenly solidified by a chilling process that crystallization is entirely prevented, and the article possesses the fine texture of natural butter.

The following drawing exhibits the microscopic appearance of butterine. The fat globules are more irregular in size than those

FIG. 2.—OLEOMARGARINE. MAGNIFIED 350 DIAMETERS.

of butter, and not so distinct. There are also a greater number of large globules than in butter fat; but on comparing Fig. 1, on page 53, with the foregoing drawing, it will be seen that the difference in their microscopic appearance is comparatively slight, and that no reliable conclusion could be founded thereon.

CHEESE.

Origin.—The great bulk of cheese is made from whole milk, but in the manufacture of some descriptions, skimmed or partially-skimmed milk is employed, while, in the preparation of a few special kinds, whole milk, enriched by the addition of cream, is used. The quality of cheese depends upon the amount of milk fat contained in the milk from which it is made, but its flavour, like that of butter, is greatly influenced by the nature of the food of the animals which yield the milk, and by the particular mode of manufacture adopted.

In this country and in America cow's milk only is used, but on the Continent that of the ewe and goat is also employed, and the cheese, in addition to being coloured and salted, as in England, is sometimes mixed with various herbs and spices.

Description.—The coagulation of the curd of the milk is effected by rennet, which, to produce a satisfactory result, requires to be prepared with great care. The time of coagulation depends partly on the temperature of the milk and partly on the strength and quantity of rennet used. The most suitable temperature for setting the milk for coagulation is 80 F. (26·6° C.); but this is subject to a variation of a few degrees,

either above or below, according as the weather is cold or warm. The conditions of setting the milk are so adjusted that, in an ordinary way, coagulation is completed in from forty to sixty minutes. If these limits are exceeded in either direction, the curd will be either tough and hard, or tender and difficult to separate from the whey without loss.

It is the practice with most cheese-makers to use artificial colouring, such as annatto. This is commonly introduced at the time of adding the rennet, and, after its addition, the milk is well stirred to ensure that the coagulum shall be of uniform tint, and that no cream shall rise before the coagulum begins to form.

When the coagulation of the milk is complete, the curd is carefully cut into small pieces by a knife, or broken down by the aid of a curd-breaker, consisting of brass-wire meshes, or of strips of tin. The operation of breaking down is conducted with great delicacy, so as to avoid bruising the curd, which would allow a portion of the fat enclosed in the coagulum to escape into the whey. When the curd has been broken into small pieces and carefully stirred, it is allowed to subside, and the whey is drawn or syphoned off. In some instances a curd-drainer, with a false bottom covered with coarse cloth, is used, and the whey passes off, leaving the curd on the cloth.

The curd is then collected in a heap, covered with a cloth to preserve the heat, and allowed to stand about an hour to develop a certain amount of acidity, which serves to harden the curd, and promote the separation of the whey.

In some cases the acidity in the curd is produced before its separation from the whey by heating the entire mass of curd and whey to a temperature of 98° F. (36·6° C.), and allowing it to stand for a short time. In other cases the requisite acidity in the curd is produced by adding about two quarts of sour whey to every hundred gallons of milk at the time of adding the rennet.

There is a process called "the sweet-curd process," in which

the curd is put into the press-vats whilst perfectly sweet, and no acid is added to, or acidity produced in, the curd before this stage; but as the curd is not salted, and nothing is present to check fermentation, the necessary amount of acidity is produced during the first few hours the curd is in the press.

The old plan of preparing the curd for vatting consisted in working it repeatedly through the fingers until it was reduced to fine pieces, but owing to the great amount of manual labour which this method involved, curd-mills were introduced, and are now generally employed in cheese factories. The grinding of the curd enables it to be packed evenly in the press-vat, assists the escape of the superfluous whey, and facilitates the uniform mixing of the salt with the curd.

Although the process of cheese-making described above is general in its essential features, yet various modifications of it are practised in districts where the cheese, such as Stilton, is of a special character.

Salting.—The quantity of salt added to the curd is generally governed by its richness in milk fat, as it would appear that a curd rich in fat requires a smaller proportion of salt than a poor one to prevent excessive fermentation in the cheese. Too much salt exercises an injurious effect by retarding fermentation and preventing the cheese from ripening.

Pressing.—The curd, when ground and salted, is transferred to press-vats and subjected to pressure for two or three days, during which time the cheese is turned once or twice daily and the wet cloths replaced by dry ones.

Curing.—From the press-room the cheese is removed to the curing-room, which requires to be maintained at a uniform temperature of about 70° F. (21·1° C.), in order to produce a mellow and sweet-flavoured cheese. A variation of temperature, rising or falling much above or below 70° F., is prejudicial to the cheese.

The ripening process is essentially a fermentative one, and during its progress the curd loses its insipidity, and acquires the characteristic taste and flavour of cheese.

The constituents of cheese are similar to those of milk, except that in the process of the ripening of the cheese, the sugar of the milk becomes transformed, partly into lactic acid, and partly into alcohol and carbonic acid.

Parasites.—Cheese, particularly the richer kinds, which are comparatively soft and loose, are liable to the attacks of certain vegetable and animal organisms. Both the blue and red moulds which develop in cheese are vegetable fungoid growths, the former belonging to the tribe of moulds termed *Aspergillus glaucus*, and the latter to that of *Sporendonema casei*. The animals known as "jumpers" are the *larvæ*, or maggots, of a fly, *Piophila casei*. The cheese-mite, *Acarus domesticus*—a microscopic animal—is of frequent occurrence in cheese, and commonly exists in great numbers.

CHEMICAL COMPOSITION.

The essential constituents of cheese are casein and milk-fat, but there are also present variable proportions of water, lactic acid, and mineral matter, including a small proportion of common salt added in the process of manufacture.

The following table contains the results of the analyses of ten descriptions of cheese, which may be taken as fairly representing the various qualities met with in commerce:

Table I.

Analyses of Ten Descriptions of Cheese.

Description.	100 Parts contain—					Proportion of Fat in 100 parts of Dry Cheese.	Proportion of Fat in 100 parts of Casein and Fat.	Salt. Per cent. in Cheese.	Percentage composition of Fat.	
	Water.	Fat.	Casein or Nitrogenous matter.	Free Acid as Lactic.	Ash.				Soluble Acids.	Insoluble Acids.
Stilton	23·57	39·13	32·55	1·24	3·51	51·19	52·50	0·67	4·42	88·96
American (Red)	28·63	38·24	29·64	—	3·49	53·57	54·12	0·72	4·26	89·06
American (Pale)	31·55	35·93	28·83	0·27	3·42	52·49	53·34	0·82	4·81	88·49
Roquefort	32·26	34·38	27·16	1·32	4·88	50·75	54·24	3·04	4·91	88·70
Gorgonzola	31·85	34·34	27·83	1·35	4·58	50·39	53·08	2·11	4·40	89·18
Cheddar (Medium)	35·60	31·57	28·16	0·45	4·22	49·02	50·49	1·43	4·55	88·75
Gruyère...	33·66	30·69	30·67	0·27	4·71	46·26	47·02	0·81	4·41	88·97
Cheshire	37·11	30·68	26·93	0·86	4·42	48·78	50·84	1·69	5·55	87·76
Single Glo'ster...	35·75	28·35	31·10	0·31	4·49	44·12	45·24	1·28	6·68	86·89
Dutch	41·30	22·78	28·25	0·57	7·10	38·80	42·41	4·45	5·84	87·58

The samples in the above table are arranged according to the amount of milk fat which they contained in their original condition, but it will be seen from the figures in column 6, that when the percentage of fat is reckoned on the dry cheese the order in which they stand is somewhat altered, and that the two American cheeses possess the advantage in point of richness. When the Stilton, Cheddar, and Cheshire cheeses are compared upon this basis, or upon that of the relation existing between the curd and fat, they are found to closely approach each other as regards richness of quality. The Dutch cheese, which stands at the bottom of the list, is a representative of a cheese prepared from milk which has at least been partially skimmed.

It will be observed from the results given in the last two columns that there is the same relation between the soluble and insoluble acids of the fat as is found to exist between these acids in milk fat. Such results tend to throw considerable doubt on the statement of M. Blondeau, and some other chemists, that a large proportion of the fat of cheese is produced from the decomposition of casein during the ripening process, for fat so produced could scarcely be expected to contain normal proportions of soluble and insoluble acids.

ANALYSIS.

The method of analysis for the determination of the fat and casein of the cheese is practically the same as that adopted in analysis, and described on pages 9 and 10. Owing, however, to the presence in the cheese of lactic acid, which is extracted by ether with the fat, it is necessary to estimate the amount of acid, and deduct the quantity from the weight of fat found, or the acid, before extraction of the fat, may be neutralised with solution of soda, and thus rendered insoluble in ether. For the estimation of the lactic acid five grams of the cheese are weighed

in a platinum capsule. The cheese is then carefully pulverised, and repeatedly washed with distilled water, until the whole of the acid is dissolved out. The washings are passed through a Swedish filter, and received in a beaker, and the acid solution exactly neutralised with a decinormal soda solution, and from the number of cubic centimetres required the amount of lactic acid is calculated.

In the estimation of the mineral matter the cheese should be neutralised with pure decinormal soda solution before ignition, and a deduction made from the amount of ash obtained, as in the case of the analysis of sour milk, described on page 14.

The soluble and insoluble acids of the cheese are determined by the process described on page 55, for the analysis of butter fat.

ADULTERATION.

Cheese has hitherto been singularly free from adulteration. Colouring matter has been about the only foreign ingredient which has been employed in its manufacture, and although it is a useless addition, and was no doubt originally intended to give a fictitious appearance of richness, yet its use has almost become a necessity to satisfy the public taste, and as serving to distinguish particular sorts of cheese. So long as the colouring matter employed is not injurious to health, there does not appear to be any good reason for objecting to its use.

The successful manufacture of factitious butter from ordinary fats of animal and vegetable origin has naturally suggested their substitution for milk fat in cheese, and it would seem that already the manufacture of "lard cheese" has developed into a considerable industry in America. The employment of ordinary fat in the manufacture of cheese affords such facilities for getting rid of skim milk, and of utilising a refuse product in butter-making, that the preparation of lard and oleomargarine cheeses is almost certain

to extend; and if a sound, wholesome fat be employed, the article will doubtless form a useful food where a low-priced substitute for a pure milk cheese is desired.

In the preparation of this compound the milk, after having been skimmed, is warmed to a sufficient temperature, and an addition is made of the quantity of lard or oleomargarine necessary to replace the abstracted milk fat. The mixture is then agitated in order to produce in the added fat as fine a state of division as possible. Rennet is afterwards added, and the coagulum which forms is then treated according to the most approved methods of cheese making.

Having been supplied with two samples of American cheese made with ordinary fat, we are enabled to give the results of their analyses in the following table:

TABLE II.—ANALYSES OF OLEOMARGARINE AND LARD CHEESES.

	100 Parts of Cheese contain—				Per Cent. of Salt.	100 Parts of Fat contain—		Melting Point of Fat.
——	Water.	Fat.	Casein and Free Acids.	Ash.		Insoluble Fatty Acids.	Soluble Fatty Acids.	
Oleomargarine	30·95	28·80	36·27	3·98	1·14	92·43	2·16	77° F.
Lard	31·30	24·66	38·87	5·17	1·55	92·88	1·55	92° F.

In flavour and character these samples closely resembled ordinary milk-fat cheese. It will be seen from a comparison of the results of the analyses of the fat of the two samples with those yielded by genuine cheeses in Table I., that the proof of admixture with foreign fat is conclusive. The low percentage of soluble acids indicates that more than one-half of the fat has not been derived from milk.

As little or no change occurs in the fat of cheese the analysis

is conducted on the same principle as that of butter, and the results obtained may be referred to the same standard in deciding whether the fat has been mixed with foreign fat or not.

Potato and other starches are included by some writers among the adulterants of cheese, but there is no reliable evidence of their having been used in this country for that purpose. The detection of starch is a matter of no difficulty, as, after the extraction of the fat from the cheese by ether, and the addition of a little iodine solution to the residue, the smallest admixture of starchy matter can be recognised by the aid of the microscope.

In some cases it is the practice to paint the outside of the cheese with Venetian red, and it is said that metallic solutions of a poisonous nature, such as sulphate of copper and lead salts, have sometimes been brushed over the outside of the cheese to preserve it from parasitic attacks. The rind should, therefore, where practicable, be carefully tested, to see that it is free from poisonous ingredients.

LARD.

LARD is the fat of the pig freed from the membranes and tissues with which it is associated when taken from the animal. In the preparation of ordinary lard, the crude fat is cut into small pieces and placed in a vessel which is heated by fire or steam. The melted fat is then drawn off into bladders or kegs, and being free from albuminous matter will keep sweet for a long time. Sometimes a proportion of salt is added during the melting of the crude fat, in which case a part thereof will subsequently be found in the lard.

Lard should be white in colour, and free from taste and smell.

It should also be practically free from water, but may contain a small proportion of salt.

The following table gives the results of the analyses of four commercial samples of lard:

ANALYSES OF LARD.

No.	Water.	Specific Gravity at 100° F.	Per cent. of Fixed Fatty Acids.	Melting point. Fahrenheit.
1	·24	904·83	95·92	109°
2	·35	903·88	95·89	108°
3	·27	903·73	95·62	111°
4	·17	903·71	95·93	114°

The only adulterant of lard which has come under our notice is water. Flour is said to have been used at one time, but its presence could be readily detected by the microscope.

CEREAL FOODS.

THE principal cereal grains used as human food are wheat, barley, oats, rye, maize, and rice. Besides these, there are some others of much less importance, such as millet, durra, etc. These grains are the seeds of various grasses, which belong to the natural order *Gramineæ*, and have hollow stems with alternate sheathing leaves, and flowers growing in spikes or panicles. The stem contains a large proportion of silica, to which it owes the strength and stiffness necessary for the support of the ear.

The cereals are the most important of all food substances, and some representative of the class exists in every part of the globe wherever agriculture is in any degree followed. The area of the cultivation of barley extends to within the Arctic circle, and from thence southward come in order, as the climate becomes warmer, oats, rye, wheat, maize, and finally, as the grain of tropical or sub-tropical regions, rice, millet, and durra. All the cereal grains, if kept dry, retain their vitality for a very long period. Grains of wheat taken from Egyptian mummy cases, and believed to have been there for two thousand years, have been planted and found to grow with ordinary vigour.

The cereals have been known from time immemorial, and the origin of individual species is quite lost, though the Egyptians had a tradition that barley was the first cereal used as human

food. Among the ancient Britons, barley was the principal grain cultivated, and was used not only for bread-making, but also for the preparation of ale, their favourite drink. In later times, and in northern countries unsuitable to the growth of wheat, rye has been largely displaced by barley and oats, while in England and other countries having a somewhat similar climate, wheat has long been the staple cereal food of the people.

In each of the cereals, the body of the grain, which consists mainly of starch, is surrounded by a testa or silicious husk, and by the difference in the structure of the tissues of the respective husks, and by the size and shape of the starch granules, it is possible, with the aid of the microscope, to distinguish the cereals from each other in a ground state.

The constituents present in the cereals are fat, starch, sugar, albuminous and other nitrogenous bodies, cellulose, mineral matter, and water, and although these occur in all, the proportion in which they are present varies considerably in the respective cereals, as will be seen from the following table:

TABLE I.—CONSTITUENTS OF CEREALS.

Constituents.	Wheat. — Winter sown.	Wheat. — Spring sown.	Long-eared Barley.	English Oats.	Maize.	Rye.	Carolina Rice without husk.
Fat	1·48	1·56	1·03	5·14	3·58	1·43	0·19
Starch	63·71	65·86	63·51	49·78	64·66	61·87	77·66
Sugar (as cane) ...	2·57	2·24	1·34	2·36	1·94	4·30	0·38
Albumin, etc., insoluble in alcohol	10·70	7·19	8·18	10·62	9·67	9·78	7·94
Other nitrogenous matter, soluble in alcohol	4·83	4·40	3·28	4·05	4·60	5·09	1·40
Cellulose	3·03	2·93	7·28	13·53	1·86	3·23	Traces
Mineral matter ...	1·60	1·74	2·32	2·66	1·35	1·85	0·28
Moisture	12·08	14·08	13·06	11·86	12·34	12·45	12·15
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00

It will be seen from the above table that the winter wheat contains more nitrogenous matter and less starch than the spring wheat. The other constituents differ but little. The oats contain more nitrogenous matter than the spring wheat, and they are rich in fat, cellulose, and mineral matter. Barley is higher than wheat in cellulose and salts, but is lower in all the other constituents. Maize stands next to oats as regards fat, but its other constituents occupy an average position with respect to wheat. Rice contains the highest proportion of starch, but the other constituents are all below the average. The constituents of rye, with the exception of the sugar, correspond closely with those of wheat.

The starch includes from one to one and a half per cent. of dextrin or soluble carbo-hydrate.

The saccharine body behaves like cane sugar in being inverted with the same facility, and in not reducing a solution of copper salt.

The albuminous compounds present in the several cereals, though having certain points of resemblance in so far as relates to their chemical composition, differ in some of their physical characters, but the differences in their behaviour with solvents do not furnish a very clear line of demarcation between them. The results obtained by different chemists in their attempts to separate the various nitrogenous bodies in cereals, have varied so as to lead to some doubt whether in any instance a pure and distinct proximate principle has been separated, whilst for quantitative analysis, any method founded on their behaviour with solvents fails to give a useful result. In the present instance we have considered it sufficient for our purpose to separate the nitrogenous substances into those soluble and insoluble in alcohol.

The soluble albuminoids of cereals which have the power of converting gelatinous starch into dextrin and maltose, possess varying degrees of activity according to the cereal from which they are derived. The difference may, however, partly arise

from their being present in greater abundance in one cereal than in another. The active principle in rye was found to have a high converting power compared with that of the other cereals, and to approach in action nearer to the diastatic constituent of germinated barley or malt, which, as is well known, acts with great energy and rapidity on soluble starch.

The albuminoids of rice exert a very weak action on starch, whilst those of oats, barley, wheat, and maize, hold a somewhat intermediate position between rye and rice.

It will be seen that the proportion of cellulose varies considerably in the cereals, ranging from a trace in rice to 13·53 per cent. in oats.

Ash.—The following table exhibits the composition of the ash of six of the cereals:

TABLE II.—CONSTITUENTS OF THE ASH OF CEREALS.

Constituents.	Wheat. — Golden Drop.	Barley.	Oats. (Middlesex.)	Rye.	Maize. (American.)	Rice without husk. (Carolina.)
Total ash on dry grain ...	1·81	2·66	3·01	2·11	1·54	·31
Potash ... ... K_2O	30·07	12·74	9·34	20·42	26·01	17·71
Soda ... ... Na_2O	·66	4·03	—	—	·91	—
Sodium chloride ... NaCl	3·05	·31	1·03	2·78	2·13	3·24
Magnesia ... ... MgO	11·39	7·59	7·75	9·23	18·73	7·86
Lime ... ... CaO	5·17	3·45	4·22	1·89	1·82	2.62
Oxide of iron ... FeO	·19	·34	·36	1·25	·52	·60
Alumina ... ... Al_2O_3	Trace	2·28	—	·11	—	—
Oxide of manganese Mn_2O_3	Trace	Trace	Trace	Trace	Trace	—
Sulphuric anhydride SO_3	3·18	1·44	3·10	1·29	1·62	·87
Phosphoric anhydride P_2O_5	45·50	39·11	32·09	48·03	47·45	65·36
Silica ... ... SiO	·79	24·70	39·56	10·43	·81	1·74
Sand	—	4·01	2·55	4·57	—	—
Total	100·00	100·00	100·00	100·00	100·00	100·00

DISEASES OF CEREALS.

It may be useful to describe shortly some of the diseases to which cereals are liable from the development of parasitic fungi. The most common of these are bunt, smut, and ergot.

Bunt.—This is also called *pepper brand*, and is botanically known as *Tilletia caries*. It is a very common disease of wheat, and grows within the seeds, ultimately developing a mass of spores which present the appearance of a fine powder. The spores are soft and feel greasy to the touch, and when rubbed between the fingers give out a disagreeable smell.

The presence of bunt in small quantity is not supposed to render flour unwholesome, but, whether or not, it should be absent in carefully prepared commercial flour. When present it can be readily identified by the microscope, the spores being large, round, and reticulated, as shown in Fig. 3. The size of the spores varies from ·0006 to ·0008 of an inch in diameter.

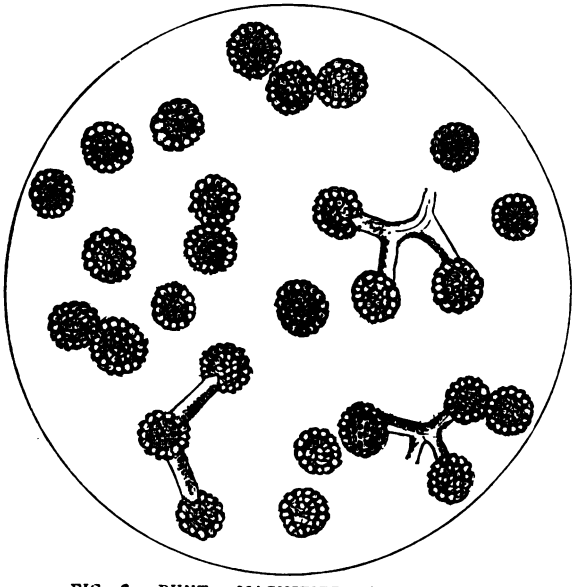

FIG. 3. BUNT. MAGNIFIED 350 DIAMETERS.

Smut.—Smut is also popularly called *dust brand*, and its botanical name is *Ustilago segetum*. It is a very common and destructive parasite, especially on barley, oats, and rye, but it seldom attacks wheat. The powder of smut resembles that of bunt in appearance, but is inodorous. Its spores are also smaller, being less than two ten-thousandths of an inch in diameter, and are not reticulated. The microscopic appearance of smut is shown in Fig. 4.

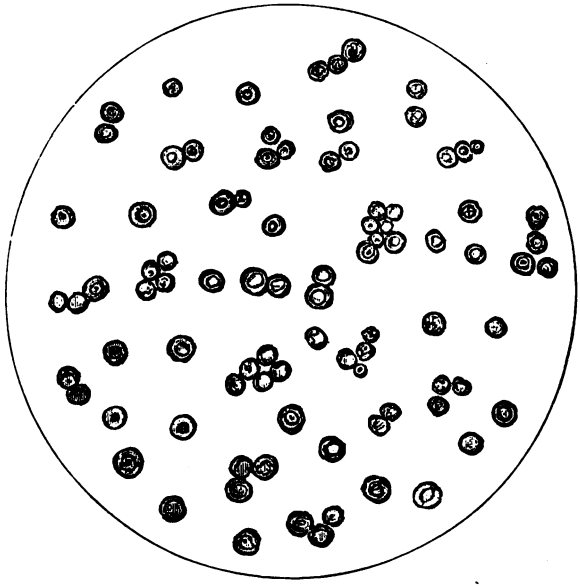

FIG. 4. SMUT. MAGNIFIED 350 DIAMETERS.

Ergot.—Ergot is almost exclusively confined to rye, wheat and other grain being only occasionally attacked by it. The

fungus is botanically known as *Oidium abortifaciens.* It begins to develop at an early stage of the germen, and eventually takes the place of the seed, one half of the whole substance being composed of *fungin*, while the cells, instead of containing starch, are filled with a peculiar fixed oil.

The spores of ergot, which are oblong in form, and not coloured blue by iodine, can be detected by the microscope when present in flour.

Ergot has an unpleasant, sour odour, and is deleterious to health.

WHEAT FLOUR.

Botanical Origin.—Wheat flour is prepared from the seed of the genus of plants called *Triticum.* There are several varieties of the wheat plant, but the differences between them are generally very slight. Some years ago (1852), M. Esprit Fabre maintained that the several varieties were derived by cultivation and selection from a grass called *Ægilops ovata*, and from the results of his experiments, he succeeded in convincing some botanists that such transformation can be effected in about twelve years.

The two varieties of wheat cultivated in this country are *Triticum hybernum* (Linn.) and *Triticum æstivum* (Linn.). The latter, which is only grown to a comparatively small extent, is also called bearded wheat, from the fact that the ears are provided with hair-like appendages termed awns, resembling those of barley, as shown in Fig. 5. The former, *Triticum hybernum*, which has

no such appendages to its ears, is often called unbearded wheat, and is shown in Fig. 6.

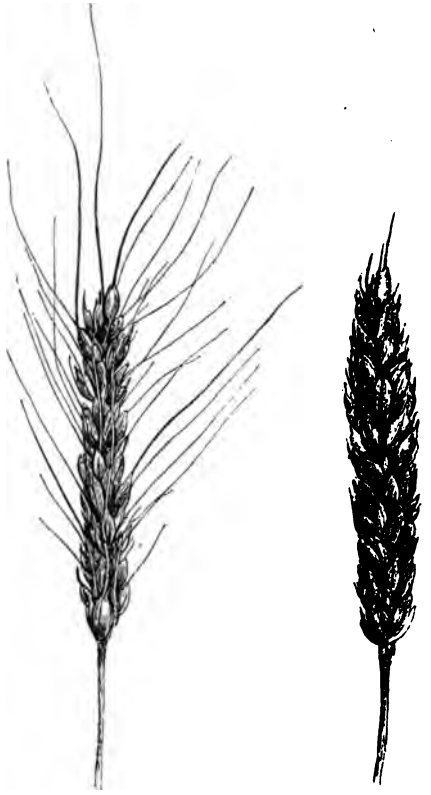

FIG. 5. EARS OF WHEAT. FIG. 6.

Formerly, the leading varieties were classified as winter and spring wheats, according as they were sown in autumn or spring; but as most varieties are now found to give a larger and finer yield when autumn sown, and as even the so-called winter wheats can be sown with safety up to the end of January, this classification

is of little value. There is, however, a natural division of the several descriptions into white and red wheats. The principal varieties of white wheat are Talavera, Rough-chaff, Smooth-chaff, Chiddam, Hunter's and Taunton Dean; and of red wheat, Golden-drop, Spalding, Lammas, Burrell, Nursery, April, and Revett's, the two last-named only being bearded. But cultivation in different soils and climates tends to produce intermediate forms which are frequently put forward as new varieties.

In addition to the foregoing, three other varieties may be mentioned.

1. The Egyptian, or many-seeded wheat (*Triticum compositum*). This is often called the "corn of abundance;" it has a branched stalk with several ears which are bearded, and the grains are thinner and less rounded than those of the best varieties of English wheat. It is said to be of African origin, and, being capable of bearing excessive moisture and heat, is the principal wheat grown in Egypt and Italy.

2. Spelt wheat (*Triticum spelta*). This variety requires less culture and attention than the better qualities of wheat, and is suitable for cultivation in poor soil. It is largely grown in the south of Europe, in several parts of Germany, at the Cape of Good Hope, and in Australia. There are two varieties of spelt wheat, one with awns, and the other without.

3. One-sided wheat, or St. Peter's corn (*Triticum monococcum*). The spike of this wheat, as its name implies, contains only one row of corns, and the stalk is shorter than that of most other varieties. There are usually four or five stems springing from each seed-corn. The grain is poor in quality, and is chiefly cultivated in mountainous regions.

The general appearance of wheat is too well known to require any lengthened description. The stalk is comparatively slender, but is specially strengthened for the support of the ear or spike by the large proportion of silicious matter which it contains; it is hollow, and knotted at intervals, and has alternate sheathing leaves.

The flowers are arranged in numerous spikelets along a common stem. Each spikelet has a pair of bracts, or glumes, which again enclose several flowers, and each of these flowers has also its own pair of bracts, called glumelles, or pales.

Description.—Wheat is not only the most valuable, but, next to maize, is the most productive of all the cereals. In a ground state, as flour, it is one of the chief necessaries of life. The wheat, having been obtained from the ears by threshing, is supplied to the miller deprived to some extent of its enveloping husks, or glumes, but before grinding it is necessary to sift the grain, so as to remove various adhering impurities, such as earthy matter, husks, etc., detached in threshing. The wheat, thus cleansed, is ground and dressed, and the quality of the flour is largely dependent on the care exercised in these operations. The following descriptions of produce are recognised, the same being classified according to the degree of fineness of the flour and the proportion of bran present:

Produce of a quarter of wheat weighing 504lbs., or 63lbs. per bushel.

Fine flour	333 lbs.
Second do.	53 ,,
Fine middlings	16 ,,
Coarse do.	18 ,,
Fine pollard	25 ,,
Coarse do.	26 ,,
Bran	26 ,,
Waste	7 ,,
	504 lbs.

A considerable amount of flesh- and bone-forming matter is removed in the middlings, pollard, and bran, and attempts have recently been made to avoid most of this loss by the introduction of what is termed "*wheat meal*," which is the flour of wheat from which only the outer integument or bran has been removed.

History.—Wheat has been known from time immemorial. Wherever the climate is suitable and the knowledge of agriculture

exists, we find wheat displacing all inferior kinds of cereals. During the feudal ages barley seems to have been replaced by rye both in England and throughout the Continent of Europe, the extravagant prices often paid for wheat showing that the use of this grain must have been confined to the wealthy. It has been estimated that the yield per acre of good land in England, in the thirteenth century, was not more than 12 bushels; in 1574 it had risen to from 16 to 20 bushels; whilst at the commencement of the present century the yield was estimated by Young at 22½ bushels per acre. Messrs. Lawes and Gilbert more recently have stated the average yield to amount to 27⅝ bushels per acre, basing their estimate upon the produce of the twenty-seven years between 1852 and 1879. During the same period, however, the acreage under cultivation in England decreased by 20 per cent., whilst the annual imports increased from 4,700,000 to 13,700,000 quarters, and the consumption of wheat per head of the population, from 5·1 to 5·67 bushels.

Wheat has been the subject of much legislation. From the year 1463, down to the abolition of the Corn Laws in 1846, Acts of Parliament were continually passed for regulating the corn trade. The exportation of wheat was forbidden when the price in the home market exceeded 6*s.* 8*d.* a quarter. In 1562 its exportation was permitted after the home price had risen to 10*s.* a quarter; a hundred years afterwards, the limit was fixed at 40*s.*; and in 1670, all restrictions on importation were virtually removed, though a customs duty was imposed which at times became prohibitive.

From 1775 till 1795, the price of wheat was under 50*s.* a quarter, but in the latter year it rose to 81*s.* 6*d.*; and in consequence of bad harvests at home and wars abroad, it continued to rise, till, in 1812, the price was 126*s.* 6*d.* During the period from 1852 to 1879, the average price of wheat was 53*s.* 5*d.* a quarter.

CHEMICAL COMPOSITION.

Wheat flour contains the following substances: starch, dextrin, cellulose, sugar, albumin, gliadin or glutin, mucin, fibrin, cerealin, fat, mineral matter, and water.

The first four are called carbo-hydrates, or non-nitrogenous substances, and they form nearly three-fourths of the entire weight of the flour. In these four alimentary principles the hydrogen and oxygen exist in the proportion to form water, and hence the application of the term to them of carbo-hydrates.

The nitrogenous matter consists of at least five principles, three of which—gliadin, mucin, and fibrin—constitute the bulk of the material known as *crude gluten*, which is the substance left when flour is kneaded with water and afterwards washed to remove the starch and any soluble substances. The remaining two nitrogenous principles, albumin and cerealin, which are soluble in water, are carried away with the starch in the process of washing.

Crude gluten possesses a peculiar adhesiveness, arising from the presence of gliadin, which is a highly tenacious body, and which is not present in the same form in other cereal flours. It is this adhesive property which gliadin imparts to gluten that renders wheaten flour so well adapted for bread-making purposes.

Although the nitrogenous matter of wheaten flour is separable into several proximate principles, yet it is doubtful whether their properties are sufficiently marked in their behaviour with solvents to found thereon a satisfactory method of analysis for their quantitative estimation, and hence, for the purpose of the present work, we have contented ourselves with the separation of the nitrogenous matter into the soluble and insoluble in alcohol of 70 per cent. The former includes the gliadin and allied substances, and the latter the albumin and fibrin.

The following table contains the results of the analyses of three samples of flour of different qualities.

TABLE III.—CONSTITUENTS OF FLOUR.

Constituents.	Household.	Best Household.	Best Whites.
Starch and Dextrin	69·04	71·05	70·33
Cellulose	·52	·70	·77
Sugar corresponding to cane sugar ...	·71	·64	·68
Albuminoids and other nitrogenous matter insoluble in alcohol ...	9·36	7·94	9·40
Nitrogenous matter soluble in alcohol	6·83	5·05	4·20
Fat	1·06	1·22	1·08
Mineral matter	·67	·73	·58
Water	11·81	12·67	12·96
Total	100·00	100·00	100·00

The mineral matter, as will be seen by Table V., consists of salts of lime, magnesia, potash, soda, and silica.

It has been stated that the external part of the grain is richer than the central in nitrogenous matter, but it will be seen from a comparison of the results of the analyses in the above table with those given in Table I. on page 86, that we have 16·19, 12·99, and 13·60 per cent. of nitrogenous matter respectively in the flours, compared with 15·53 and 11·59 in the entire grain.

The chemical constituents of wheat flour are so proportioned as to render it of high nutritive value, and consequently it forms one of the most useful of vegetable foods.

Starch ($C_{12}H_{20}O_{10}$).—This is the most abundant, if not the most important constituent of flour. It is almost wholly present, in the insoluble condition, and in the form of rounded

granules of various sizes, ranging in diameter from ·0011 inch downwards.

The starch of wheat can be recognised by the aid of the microscope, and be distinguished from that of nearly every other cereal.

Starch is without smell or taste, and is always white, with more or less of a glistening appearance. Its specific gravity varies from 1·55 to 1·60, which is about that of cane sugar, and it undergoes remarkable changes under the influence of certain soluble albuminous substances which exist ready formed in grain. It is similarly changed by saliva.

The activity of the soluble albuminoids of grain is much increased by subjecting the grain to incipient germination, and their effect upon starch is greatest when the latter is in a gelatinous condition. The first change of the starch is into a soluble state, then into one or more forms of dextrin, and finally into maltose, a sweet substance capable of crystallisation, and having the composition of cane sugar. Similar transformations take place when starch is boiled with dilute sulphuric acid, but in this case the ultimate product is glucose or dextrose. Maltose, when boiled with dilute sulphuric acid, is also converted into dextrose.

When starch is heated with water, the granules swell up and then burst, forming a gelatinous mass, but when starch in a dry state is gradually heated to 320 F. (160° C.), the product is dextrin accompanied with a little saccharine matter. It is then soluble in water, and forms the article commercially known as British gum.

Dextrin, $C_{12}H_{20}O_{10}$.—This body is usually present in very small quantity, and, like sugar, its proportion, if not its presence, depends upon the curing and mode of treatment of the wheat and flour.

Dextrin is an intermediate compound between starch and

sugar, and is produced, under certain conditions, by the action of albuminoids on the former, and also, by the action of heat, as already stated.

Cellulose, $C_{12}H_{20}O_{10}$.—Cellulose forms the basis of the substance composing the walls of the cells and vessels of vegetable structures. It is present to a very limited extent in the starchy portion of the grain from which the flour is derived, but it enters more largely into the composition of the external coats of the seed, and on the entire grain amounts to about three per cent. In flour the quantity is less than one per cent.

Cellulose is not readily soluble, but it yields to the action of both alkalis and mineral acids. In flour it exists in a finely divided state, and in that condition is readily acted upon by chemical agents.

Sugar, $C_{12}H_{22}O_{11}$.—It will be seen from the above table that the quantity of sugar obtained was less than 1 per cent. in each of the three flours. The sugar present corresponded in properties to cane sugar. It is not readily dissolved by 92 per cent. alcohol, but it can be easily extracted by alcohol of 70 per cent. It does not reduce cupric tartrate, but possesses that property after the treatment with sulphuric acid which suffices for the inversion of cane sugar.

The entire grain of wheat contains a larger proportion of sugar than the starchy interior, and the same remark applies to all the cereals. It is probable that both the proportion and character of the saccharine matter in flour vary according to the conditions of harvesting. In bad seasons, when the wheat is exposed to much wet, and the circumstances are favourable for the action of the diastase-like principle contained in the grain, we should expect to obtain an increased proportion of saccharine matter.

Albumin.—This body is present in considerable quantity in wheat flour, where it exists, as in most other vegetable substances,

in a form in which it can be removed by treatment with cold water. Vegetable albumin closely resembles, in appearance and in its behaviour with acids and alkalis, the albumin obtained from the white of egg and the serum of blood. It forms when moist a white elastic mass which, on drying, acquires a yellow colour and horny appearance. In contact with water, the dried substance again absorbs several times its weight of that liquid, and assumes much of its original character. A solution of albumin is readily precipitated by nitric or hydrochloric acid, but such acids as acetic or tartaric have no effect upon dilute solutions. Tartaric acid by the aid of heat, and dilute alkalis in the cold, dissolve coagulated albumin, whilst concentrated alkalis convert it into the form of a jelly.

Gliadin, or Glutin.—It is to this substance that bread made from wheaten flour owes its well-known porous and spongy character, and its deficiency in the other cereals unfits them generally for bread-making. In the hydrated condition it is of a soft and pasty character and can be drawn out into threads. When dried in air or in the water-bath, it resembles gelatin, but when dehydrated by alcohol and ether, and dried in vacuo, it forms a hard mass easily reducible to powder. When gliadin is left in contact with water for some time, it decomposes and gradually passes into solution, in which state it acts upon starch in a way very similar to that of the soluble albuminoids. Gliadin is insoluble in cold water and only slightly soluble in hot water, but readily soluble in the fixed alkalis and in alcohol of 70 per cent.

Mucin.—This is a body having much the same properties as gliadin. It dissolves in hot alcohol along with the latter, but is slowly deposited in a flocculent condition as the spirit cools. In its several characteristics it appears to come between gliadin and vegetable fibrin.

Fibrin, or insoluble Albumin.—This is the portion of the albuminous matter insoluble in water and alcohol. When crude gluten is exhausted with alcohol the fibrin remains as a grayish-white, elastic mass, intermixed with starch and cellulose, from which it may be purified by solution in potash and precipitation by acetic acid. When dry, it becomes of a brownish colour, and acquires a horny appearance, but it recovers its original condition when left in contact with water. It is dissolved by dilute hydrochloric acid, and also by acetic, tartaric, and phosphoric acids, and is precipitated when such solutions are neutralised.

Cerealin.—This, according to Mège-Mouriès, exists as a proximate principle in the seed-coats of wheat. It is largely removed with the bran in the process of manufacture, and consequently is present to a very limited extent in flour. It is said to possess properties similar to those of diastase, and to have the power of converting starch into dextrin and maltose. According to the same authority, bran contains another nitrogenous principle which acts upon starch with even greater energy than cerealin. It is supposed that the dark colour of brown bread is due to the action of cerealin, and that if the activity of this body be destroyed by heating the flour, a comparatively white bread may be made from the entire flour of wheat.

The action of cerealin upon starch is prevented by the presence of alkalis, and its effect closely resembles that of the soluble albuminoids of malt. If to a quantity of thick gelatinised starch at 122° F. (50° C.) an aqueous infusion of bran or a similar infusion of malt be added, the mixture rapidly liquefies and becomes sweet, owing to the transformation of starch into dextrin and maltose.

Fat.—Flour contains an oily fat, but only in small quantity, and always less than in the corresponding whole grain.

Ash.—The ash of ordinary flour, as will be seen from the following table, varies from about ·35 to ·86 per cent.

TABLE IV.

RESULTS OF A PARTIAL ANALYSIS OF FLOUR.

No.	Description.	Percentage of		Per 4 lbs. of Flour.		
		Moisture.	Inorganic Matter.	Silica (Grains).	Phosphate of Alumina (Grains).	Corresponding weight of Ammonia Alum (Grains).
1	Hungarian	11·36	·35	2·52	·74	2·73
2	ditto	9·94	·61	24·92	2·05	7·58
3	ditto	9·84	·40	5·60	1·86	6·88
4	American	12·02	·86	1·40	1·30	4·81
5	ditto	11·58	·56	1·12	·56	2·07
6	ditto	11·94	·84	1·40	·93	3·44
7	Odessa	11·20	·41	1·30	·74	2·73
8	ditto	11·76	·59	4·08	1·12	4·14
9	ditto	11·58	·70	7·84	1·30	4·81
10	Dantzic	11·80	·67	6·72	2·61	9·66
11	Australian	11·94	·68	6·12	1·12	4·14
12	Baltic Whites ...	11·70	·65	2·08	·93	3·44
13	Whites	11·62	·60	8·96	1·12	4·14
14	ditto	11·84	·72	10·92	1·12	4·14
15	Seconds	11·70	·67	3·36	·93	3·44
16	Household	12·72	·68	12·32	2·05	7·58
17	ditto	12·12	·68	4·76	2·24	8·29
18	ditto	12·46	·76	11·20	2·80	10·36
19	ditto	12·60	·86	15·12	2·42	8·95
20	ditto	13·62	·64	17·96	2·80	10·36
21	ditto	13·47	·71	14·56	5·88	21·76
22	ditto	16·05	·78	25·85	11·48	42·50
23	ditto	16·58	·55	8·58	5·04	18·65

The samples in this table were all examined for alum, but none was detected in any of them.

One of the most notable features about the results, is the wide variations which occur in the calculated amount of alum corre-

sponding to the alumina actually found in the different samples, the quantity ranging from 2·07 to 42·50 grains of ammonia-alum in the 4 lbs. of flour. The amount of silica is also very variable, ranging from 1·12 to 25·85 grains in the 4 lbs.; but with the increments in the proportion of silica there is no uniformly corresponding increase in the amount of alumina, and consequently there does not appear to be any definite relation existing between these two constituents, from which any reliable conclusion could, without further evidence, be formed of the addition of alum.

The following table exhibits the composition of the ash of a sample of household flour:

TABLE V.

Constituents.		Per cent.
Total ash on dry flour		·74
Potash	estimated as K_2O	15·62
Potassium chloride ...	,, ,, KCl	2·12
Sodium chloride	,, ,, NaCl	·68
Magnesia	,, ,, MgO	10·44
Lime	,, ,, CaO	5·26
Oxide of iron	,, ,, FeO	·97
Alumina	,, ,, Al_2O_3	Trace
Oxide of manganese ...	,, ,, Mn_3O_4	Trace
Sulphuric anhydride ...	,, ,, SO_3	1·19
Phosphoric anhydride ...	,, ,, P_2O_5	60·58
Silica	,, ,, SiO_2	1·36
Sand	... ...	1·78
	Total	100·00

MICROSCOPIC STRUCTURE.

Ground wheat contains several distinct forms of tissue derived from the testa or skin of the grain. The testa is composed of three membranes; the first two, which consist of elongated cells surrounded by beaded walls, and lying transversely to each other, are represented at A and B, Fig. 7. The third tissue, which is seen

at C, is composed of roundish and somewhat angular cells, containing oil globules and molecular matter in a very fine state of division, and presenting an opaque appearance. The cells forming the tissues of the testa gradually diminish in size, as they recede from the centre of the grain and approach either end.

In addition to these, occur unicellular hairs which are represented at D. These are attached to the testa at the end of each grain. They vary greatly in size, but are all pointed at the apex.

The interior of the grain consists principally of thick-walled cells filled with starch granules, the cells being surrounded by albuminous and other nitrogenous substances, but possessing no distinctive structure.

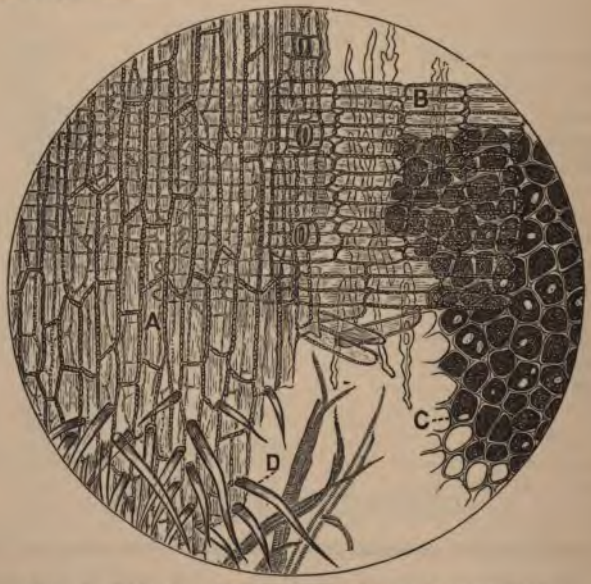

FIG. 7. SKIN OF WHEAT. MAGNIFIED 100 DIAMETERS.

The granules of wheat-starch are shown in Fig. 8. They vary in size from one ten-thousandth of an inch in diameter to

eleven ten-thousandths of an inch. Each granule has a hilum or central spot, and the small ones, when examined by a high magnifying power, are seen to be distinctly angular. Many of the large granules are somewhat flattened on one side, and exhibit faintly marked concentric rings.

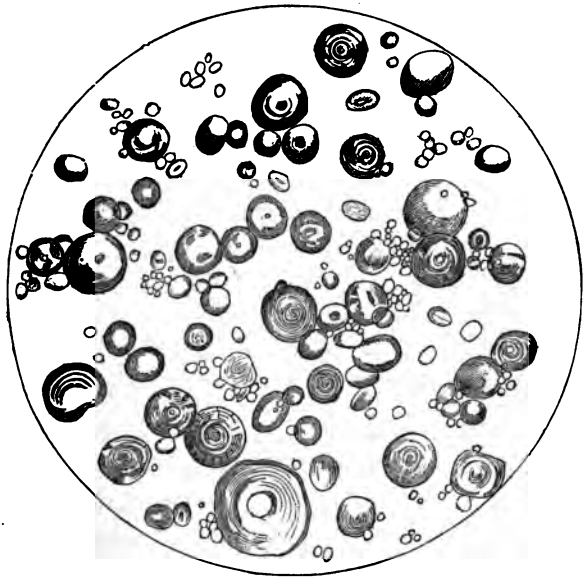

FIG. 8. WHEAT STARCH. MAGNIFIED 320 DIAMETERS.

ANALYSIS.

Starch.—Starch is estimated from the amount of glucose which is produced from it by the action of sulphuric acid. For this purpose 2 grams of the flour are boiled for six hours with about 100 cubic centimetres of water and 20 cubic centimetres of normal sulphuric acid in a flask fitted with a condensing apparatus. When the conversion of the starch is completed, the solution is neutralised with soda, made up to a bulk of 500 cubic centimetres, and the amount of glucose present therein

estimated either volumetrically or gravimetrically by a solution of cupric tartrate, in the manner described on p. 106, Part I. After deduction of the sugar naturally present, the difference is the amount produced from the starch, together with a small quantity from the dextrin, and probably also from a conversion of traces of the finely-divided cellulose. As 90 parts of starch yield 100 parts of glucose, the proportion of starch in the flour is readily calculated. When the amount of starch in the cereal is required, it is advisable to boil a weighed quantity of the finely-powdered grain for ten minutes in water acidulated with 5 cubic centimetres of normal sulphuric acid, which renders the starch soluble. The solution is filtered, and the undissolved part of the grain well washed with hot water until all evidence of starch has been removed; 15 cubic centimetres more of normal sulphuric acid are then added to the starch solution, and the boiling continued, as in the case of flour, for six hours, to ensure the complete conversion of the starch into glucose.

Cellulose.—Five grams of flour or finely-powdered grains, are boiled in 100 cubic centimetres of water, acidulated with 10 cubic centimetres of normal sulphuric acid, for ten minutes, or until all the starch is dissolved. A large quantity of water is then added, and the undissolved part allowed to subside. The liquid part is then decanted, and the residue, after being thrown on a filter and well washed with boiling water to remove starch, is digested for a short time with water containing 10 cubic centimetres of normal potash solution, whereby nearly all the albuminous matter is dissolved. After filtration the residue is warmed with about 200 cubic centimetres of water rendered slightly alkaline with potash, then thrown on a tared filter, washed, dried, and weighed on the filter. It is then incinerated, and the amount of the ash deducted from the weight of cellulose found.

Sugar.—10 grams of the flour or powdered grain are repeatedly digested in alcohol of 70 per cent., and the filtrate

made up to a bulk of 300 cubic centimetres. The solution is first tested directly for glucose, but the result is generally a negative one. A known portion of the filtrate is next boiled for four minutes with 5 cubic centimetres of normal sulphuric acid, and then neutralised with soda and tested with solution of cupric tartrate according to the method given in Part I. page 106, and from the result the amount of sugar present, reckoned as cane, is calculated.

Nitrogenous Compounds Soluble and Insoluble in Alcohol.—For the purpose of making this determination, 10 grams of the flour are completely exhausted with alcohol of 70 per cent., at a temperature of 140° F. (60° C.) and an aliquot part of the total filtrate evaporated to dryness and weighed. A known quantity of this residue is submitted to combustion with copper oxide, and the proportion of nitrogen found multiplied by 6·3 gives the quantity of glutinous matter present. The flour left after treatment with alcohol is dried, and a weighed portion analysed for nitrogen, from the amount of which the percentage of albumin and fibrin is calculated as before mentioned.

Albumin.—Although it has not been deemed desirable, for the reasons stated on page 87, to attempt the separation of the several nitrogenous compounds of flour, it may be useful to point out the means by which they may be roughly estimated.

For the estimation of albumin 20 grams of flour are well shaken up with water at the ordinary temperature, and, after subsidence of the insoluble matter, the clear liquid is decanted and filtered. The operation is repeated with a fresh quantity of water, and the filtrates added together and boiled. The albumin is deposited in flocculent masses, and, after being well washed with water, is purified from adhering fat or other matter by digestion with boiling alcohol and ether.

Crude Gluten.—This body is an impure mixture of gliadin, mucin, and fibrin, and is obtained by kneading out in water the

starch, soluble albumin, sugar, etc., from a mass of dough. There are several methods given for effecting this object, but the simplest way is to mix a weighed quantity of flour into a dough with a little water, and then knead the dough in a fine linen cloth under a gentle stream of water until all the starchy and soluble matters are removed. The product is spread out in a thin layer, dried in a water-bath and weighed. Crude gluten so obtained contains from one to one and a half per cent. of fat and inorganic matter.

Gliadin and Mucin.—According to the method proposed by Ritthausen, crude undried gluten, obtained as just described, is digested several times with boiling alcohol of 80 per cent. and rapidly filtered after each operation. The filtrates, which become turbid on cooling, from separation of mucin, are distilled, and after half the alcohol has been distilled off, a considerable quantity of flocculent mucin separates on cooling from the residual fluid. The precipitate is purified by being dissolved in alcohol of 50 per cent., filtered while hot through calico, and then left to deposit on cooling. It is then transparent, flocculent, and slightly coloured. The alcohol from which the mucin has separated contains the gliadin, but it requires to be purified from a little mucin which still remains. This is effected by evaporating the alcohol over the water-bath, when the mucin is rendered insoluble. The gliadin is then redissolved in alcohol or acetic acid, and is obtained pure by evaporation of the solution to dryness.

Fibrin.—This body is obtained as an insoluble product when crude gluten is digested with boiling alcohol of 80 per cent. as above described.

Cerealin.—This, as stated in another place, is principally present in the seed-coats, and is therefore contained but to a small extent in ordinary flour.

To obtain it Mège-Mouriès digested bran repeatedly in dilute

alcohol until all the sugar, dextrin, and soluble albuminoids were removed. The residue was then treated with water to dissolve the cerealin, which on subsequent evaporation of the solution at a low temperature was left in an amorphous state.

Fat.—Four grams of the flour are dried and repeatedly digested with ether until exhausted of fat. The filtrates are evaporated in a tared beaker and weighed.

Ash.—Ten grams of flour are incinerated in a platinum capsule to a white ash, which is then weighed. The amount found in the case of an ordinary flour should not exceed one per cent.

ADULTERATION.

Many substances, both of vegetable and mineral origin, have been found from time to time as adulterants of flour, the principal of which are ground beans, peas, rye, barley, and rice, alum, chalk, gypsum, soapstone or silicate of magnesia, and carbonate of magnesia.

The use of most of these adulterants is now comparatively rare; and since the passing of the "Food and Drugs Act, 1875," the principal adulterant found by the public analysts has been alum.

Most of the vegetable adulterants mentioned can be readily detected by the microscope, by the size and shape of the starch granules; but barley-starch, the granules of which closely resemble those of wheat, is more difficult of identification. In the case of rye-starch, the cracked edges and star-like hilum of some of the larger granules are very characteristic; but the recognition of the starch of barley-flour by the microscope cannot be relied on alone, and confirmatory evidence of its presence must be

sought from portions of husk which may be found. The illustrations of the starches and husks of cereals given on pages 117 to 123 will be of service in the identification of adulterants of flour.

The mineral adulterants of flour are readily detected. The amount of ash affords an indication at once of such as are added for mere increase of weight; but with alum the amount required to be added to produce the desired result is so small that no indication of its presence is given by the amount of ash. There are, however, other tests available for proving the presence of alum in flour, even when the quantity is so small as one grain per pound.

One of these tests is based upon the well-known property possessed by alumina, of forming a violet or lavender-coloured *lake* with the colouring matter of logwood. This test, which is readily applied, is one which we have never known to fail to indicate alum whenever present in flour, but it requires to be used with certain simple precautions, to the neglect of which its failure in the hands of some analysts can only be ascribed. The reagents required are recently-prepared tincture of logwood and a solution of carbonate of ammonia. The former is prepared by digesting 5 grams of logwood chips in 100 cubic centimetres of strong alcohol; and the latter by dissolving 15 grams of carbonate of ammonia in 100 cubic centimetres of distilled water. The test is applied as follows: A small quantity, say 5 grams of flour, is made into a paste with 5 cubic centimetres of water; one cubic centimetre of the logwood solution is then mixed with the paste, and this is followed immediately by the addition of one cubic centimetre of the solution of carbonate of ammonia. If alum be present the colour produced will be more or less lavender or blue, according to the quantity of alum in the flour; but if the colour be pink, which soon fades to a dirty brown, then, according to our experience, alum is invariably absent. Should there be any doubt as to the colour, the paste is put aside for several

hours, and then, if alum be present, even in very small quantity, there will be a decided tinge of lavender on the sides of the capsule near the edge of the partly-dried paste. An approximate estimate of the quantity of alum present may be formed by making comparative experiments with flour, to which different quantities of a solution of alum of known strength have been added, and judging by the depth of the lavender or blue colour produced. Valuable, however, as is the logwood test in showing the absence of alum, yet the production of a lavender tinge must not be considered conclusive proof of the presence of alum, or of any other soluble salt of alumina, without further evidence, as there are certain other salts, particularly those of magnesia, which produce a somewhat similar colour, though not of so permanent a character.

A ready method of separating alum and other mineral matter from flour is to agitate the latter with chloroform in a glass vessel known as a separator, and allow the mineral matter to subside. A known quantity, say four ounces of flour, is placed in the separator with ten or twelve fluid ounces of chloroform, and the vessel is then well shaken so as to bring the chloroform into contact with every particle of the flour. On standing, the flour rises to the surface, and most of the foreign mineral matter settles to the bottom, and may be drawn off by the tap. A further small quantity of mineral matter may be obtained by repeating the shaking and settling alternately for a number of times, care being taken to avoid disturbing the sediment as it is formed. Mineral matter thus obtained is purified by one or two further treatments with chloroform in a small separator; it is then dried at a very gentle heat, and weighed. It is next examined by the microscope to ascertain if any husk or starch be present, and for any evidence which may be afforded by its granular or crystalline nature. The residue is then exhausted, first with cold water, and subsequently with very dilute hydrochloric acid, and afterwards washed, ignited, and weighed. The residue will contain the sand, clay, and other

impurities from the soil or millstones, as well as any insoluble earthy matter which may be present in the flour. The neutralised extract of the residue, and also a portion of the aqueous extract, are respectively submitted to the logwood test, and should the presence of alumina be indicated, the sulphuric acid in the remainder of the aqueous extract is estimated as barium sulphate, and, provided that no other soluble sulphate is present, a close approximation to the amount of alum added may be calculated therefrom.

Estimation of Alum.—Many processes have been proposed for the quantitative determination of alum in flour and bread, most of which are only different modes of estimating the amount of alumina, generally in the form of phosphate. We have tried several methods, but the following modification of that proposed by Dupré is the one which we have found to be the most trustworthy. One hundred grams of flour, or the crumb of bread, are carefully incinerated in a platinum capsule over a Bunsen burner until the ash is nearly white. A quantity of the mixed carbonates of potassium and sodium, known to be free from alumina, in proportion equal to about four times the weight of the ash, is then added, and the whole thoroughly fused. The fused mass is dissolved in excess of hydrochloric acid, and the solution afterwards evaporated to dryness, and gently ignited to render the silica perfectly insoluble. Dilute hydrochloric acid is next added to the residue, which is then heated. The solution is afterwards filtered, and the insoluble silica left on the filter ignited and weighed. To the filtrate ammonia is added until a slight permanent precipitate is produced, which is then redissolved by a few drops of strong hydrochloric acid. A slight excess of acetate of ammonia is next added, and after the appearance of the precipitate has been carefully noted, the mixture is raised to the boiling point, at which it is maintained for a few minutes, and then set aside for several

hours. If the appearance of the precipitate becomes more granular during the boiling, or increases very largely in quantity, as will sometimes be the case, it is evident that phosphates of lime and magnesia have been precipitated, and the precipitate must be filtered off, dissolved in a little hydrochloric acid, warmed and reprecipitated as before with acetate of ammonia solution. The precipitate is filtered off, washed, and again dissolved in a small quantity of hydrochloric acid. The solution is boiled for a few minutes with about five grains of bisulphite of soda, and again for a few minutes longer after the addition of an excess of pure caustic soda. The precipitate of oxide of iron is filtered off, and the filtrate slightly acidified by hydrochloric acid. Acetate of ammonia in slight excess is then added, and the solution raised to the boiling point, and allowed to stand for several hours. The resulting precipitate, which should consist of pure phosphate of alumina, is washed, dried, ignited, and weighed. The weight of the precipitate multiplied by 3·873 or 3·702 gives the amount of potash-alum or ammonia-alum respectively, corresponding to the total alumina in the one hundred grams of flour or bread taken. Before accepting the result as conclusive, care should be taken to prove that the precipitate consists of phosphate of alumina only.

In this process for estimating alumina as originally proposed, the phosphate of alumina was precipitated in the cold, but in our experiments on flour containing known quantities of alum, it was found that the whole of the alumina of the alum was not precipitated in the cold even after standing overnight, and that the quantity remaining in solution could be recovered by boiling. It is true that by so doing there is increased danger of the precipitate containing phosphates of lime and magnesia, but this contingency is fully provided against by repeating the precipitation in the presence of free acetic acid, and subsequent treatment with pure soda.

Another, and much more simple process for the quantitative estimation of alum in flour and bread, has been proposed by Wanklyn. It is based upon the presumed complete solubility of the earthy phosphates in an excess of acetic acid at the boiling temperature, and the precipitate obtained is assumed to consist only of the phosphates of alumina and iron; but, according to our experience, the results so obtained are much in excess of the truth.

All wheat flours and breads contain small proportions of alumina in the form of silicate, for which an allowance requires to be made in calculating the amount of alum present. It has been the practice of some analysts to make an allowance of alumina on this account, corresponding to 10 grains per 4 lb. of flour, but investigations by ourselves and others have shown that such an amount is not in all cases sufficient, and that some flours contain alumina, in the form of silicate, equivalent to more than 40 grains of alum in 4 lb. No rule can be laid down for the correction which should be made for the alumina naturally or incidentally present in flour, as, owing to the variable nature of soils, the relation of the silica to the alumina is not constant. The analyst should therefore take into consideration, not only the relative amounts of silica and alumina obtained, but also the indications afforded by the application of the logwood test.

Some descriptions of wheat, notably Egyptian, are imported into this country containing a considerable quantity of earthy matter. In two samples of Egyptian wheat examined by us, there were, besides clayey matter attached to the grains, 3·3 and 3·7 per cent. respectively of small stones. When the samples were shaken with water, most of the earthy matter was detached, the water becoming very turbid, but part remained in the furrows of the grains. After removal of the small stones, the samples were examined for silica and alumina, both before and after

the above-mentioned washing, and the following results were obtained:

Egyptian Wheat.	Before washing.			After washing.		
	Per 4 lbs.			Per 4 lbs.		
	Silica.	Phosphate of Alumina.	Corresponding Ammonia Alum.	Silica.	Phosphate of Alumina.	Corresponding Ammonia Alum.
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
No. 1 ...	25·76	7·84	29·02	12·32	2·24	8·29
No. 2 ...	23·33	7·84	29·02	14·18	2·80	10·36

When alum is added it is generally on account of the unsoundness or inferiority of quality of the flour, as even in very small proportion it has a remarkable power of improving the colour and general appearance of bread made from such flour. Its mode of action is somewhat obscure, but its effects are:—1st, the retarding of the decomposition of the nitrogenous constituents, thus checking an excessive action upon the starch, to which in unsound flour there is a tendency; and 2nd, the hardening of the gluten, whereby increased porosity is produced, and an appearance of greater whiteness given to the bread.

It will be seen from the table on page 102 that the amount of ash in ordinary flour varies from ·35 to ·86 per cent.; and if the quantity exceeds one per cent. there is evidence of an addition, accidental or intentional, of earthy matter. A qualitative examination as to the solubility of the ash in water, and its effervescence with and solubility in dilute hydrochloric acid, will readily afford information as to its nature. If a large proportion of it be insoluble in dilute hydrochloric acid, the portion so insoluble should be fused with alkaline carbonates to ascertain whether it consists of adventitious sand or clay, or of added gypsum (sulphate of calcium), barytes or heavy spar (sulphate of

barium), or soapstone (silicate of magnesium). If necessary, a larger quantity of the flour can then be ignited for a quantitative estimation of the adulterant found, or a portion of the flour may be agitated with chloroform, as described on page 111, when the adulterant will be found in the mineral matter which subsides.

MICROSCOPIC EXAMINATION.

The microscope is relied upon for the detection of adulteration of wheat flour by any foreign cereal flour, or by flour prepared from beans or peas. A little practice in the examination of the different starches enables the operator to readily distinguish most starches from each other.

Where starches, such as those of wheat and barley, are so nearly alike, and difficult to distinguish the one from the other, it is possible sometimes to detect pieces of the tissues of the husk of the grain, from which the presence of the suspected foreign flour can be confirmed.

Barley Flour.—The husk of barley is composed of five membranes or tissues. The first two are shown in Fig. 9, and the other three in Fig. 10. The first or outer tissue consists of long narrow cells, with well-marked, serrated edges, and containing silica in the form of small round, flattened discs. Immediately underneath this membrane are several rows of spiral tissue running throughout the entire length of the grain. The second tissue consists of long, thin, woody cells, with pointed ends. The third tissue, Fig. 10, consists of a double layer of large rectangular cells, the edges of which are beaded, but not so distinctly as in the corresponding membrane of the testa of wheat. The fourth tissue is formed of narrow, elongated cells, lying transversely to the cells of the third membrane. The fifth or inner membrane is composed of rounded cells filled with molecular matter in a fine state of division. There also occur in barley meal a number of short, thick, spinous hairs, which are attached to the husk at the end of each grain, and which can be readily identified.

FIG. 10. HUSK OF BARLEY. MAGNIFIED 100 DIAMETERS.

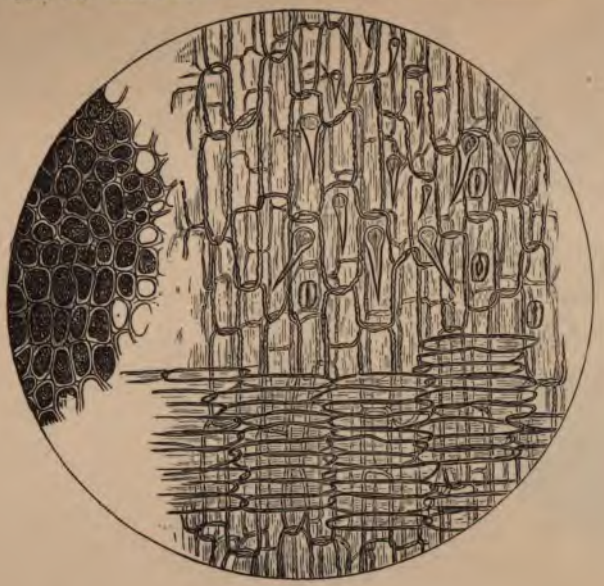

FIG. 9. HUSK OF BARLEY. MAGNIFIED 100 DIAMETERS.

The granules of barley starch are shown in Fig. 11. They are generally of about the same size and form as those of wheat,

FIG. 11. BARLEY STARCH. MAGNIFIED 320 DIAMETERS.

but rather more irregular in shape, and some of the larger granules are more distinctly marked with concentric rings. The granules vary in size from ·0001 to ·0011 inch in diameter.

Rye.—The testa of rye is composed of three membranes, which closely resemble the corresponding ones forming the testa of wheat. The first or outer tissue is represented at A, the second at B, and the third at C, Fig. 12. The cells of both tissues A and B are elongated and have beaded edges, and

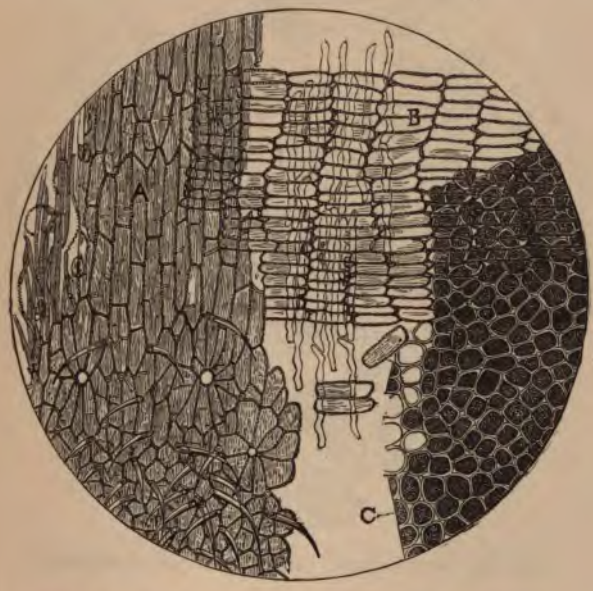

FIG. 12. SKIN OF RYE. MAGNIFIED 100 DIAMETERS.

the cells of the latter lie transversely to those of the former. Delicate spiral tissue occurs immediately under the outer membrane along the furrow in the under side of the grain. At one end of the grain unicellular pointed hairs are attached to the testa. These hairs are shorter than those found in wheat.

The microscopic appearance of rye starch is shown in Fig. 13. The granules are larger than those of wheat or barley, more circular in form, and present a flattened appearance and fractured

FIG. 13. RYE STARCH. MAGNIFIED 320 DIAMETERS.

surface. The majority of the granules also exhibit a stellate hilum, and some have lines or furrows diverging from the centre and extending to the edge of the granule.

Rice.—The granules of this starch are represented in Fig. 14. They are the smallest of all the commercial starches, and vary

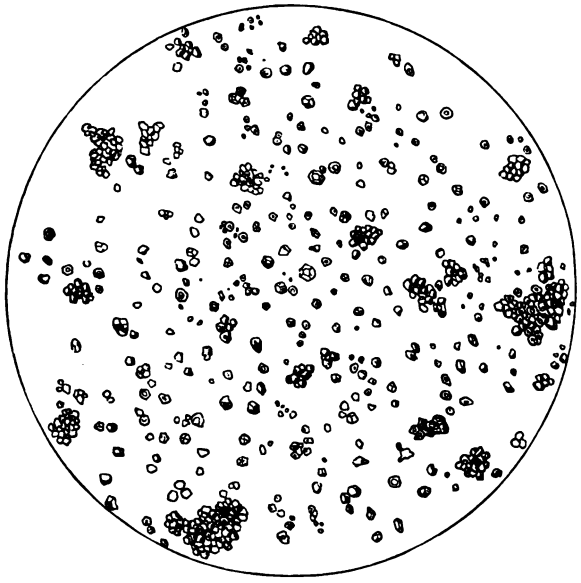

FIG. 14. RICE STARCH. MAGNIFIED 320 DIAMETERS.

in size from ·0001 to ·0003 of an inch in diameter. They are generally pentagonal or polygonal in form, with an extremely minute and almost imperceptible hilum.

Bean and Pea Starches.—The microscopic appearances of these starches are shown in Figs. 15 and 16. They are so similar in appearance that the same description will apply to both. The granules are oblong, kidney-shaped, and irregularly formed, and most of them have a longitudinal cavity which runs along each granule lengthwise, and from which in many instances furrows diverge to the right and left, imparting to their surfaces a fractured appearance.

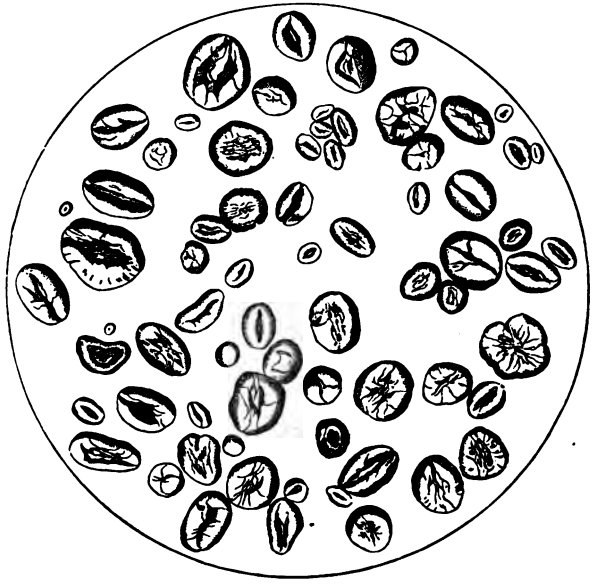

FIG. 15. BEAN STARCH. MAGNIFIED 320 DIAMETERS.

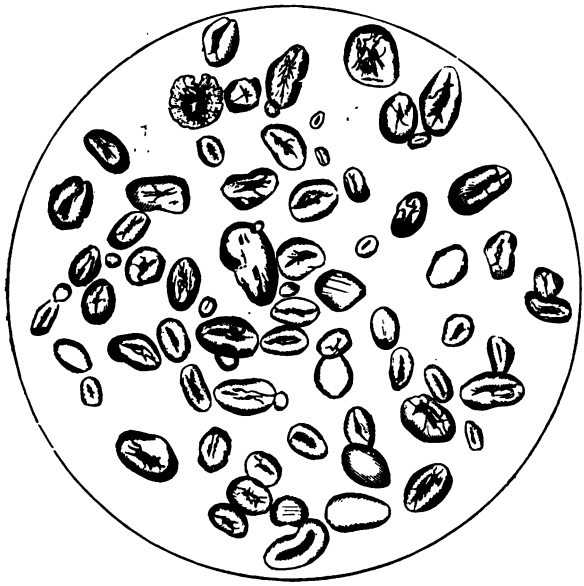

FIG. 16. PEA STARCH. MAGNIFIED 320 DIAMETERS.

BREAD.

Description.—The term Bread is applied to several descriptions of human food prepared by mixing flour or meal with water into a paste which, when formed into various shapes and degrees of thickness according to taste, is baked or dried by natural or artificial heat. The cereals used are Wheat, Rye, Barley, Oats, Maize, and Rice; but Wheat far exceeds all the others in its suitability for the purpose, and in the extent to which it is employed. The name given to the bread produced varies with the ground cereal which has been used, its freedom from husk or otherwise, and according as the paste has been baked in a leavened or unleavened state.

Unleavened bread is made by mixing the ground grain, with or without its husk, into a paste with water, to which a little salt is added, and then baking it in cakes. In this way are prepared the *passover-cakes* of the Jews, the *oat-cakes* and *bannocks* of Scotland, the *corn-bread* of America, and the *dampers* of Australia. This kind of bread has the advantage of being easily and quickly made; but it is sodden and less digestible than leavened bread, especially if wheaten flour be used.

Leavened or fermented bread is made by subjecting the dough to fermentation, by means of leaven or of yeast, prior to its being baked. Leaven, which has been used from very ancient times, is dough, generally from a previous baking, containing an active ferment and possessing the power of exciting fermentation in any fresh dough with which it is incorporated. The leaven or yeast, as the case may be, is kneaded with the fresh dough, and is thus brought into contact with every part of the flour; and at the same time a quantity of air is enclosed which favours the subsequent

fermentation. The dough is then set aside in a warm place for several hours to ferment. During this process a portion of the starch is converted into saccharine matter, which in part is immediately decomposed into alcohol and carbonic acid gas, the latter forming innumerable cavities throughout the dough and causing it to increase largely in bulk. The dough is then baked in an oven at a temperature varying between 320° F. (160° C.), and 572° F. (300° C.); the alcohol and carbonic acid gas are expanded and subsequently expelled, the fermentative agents destroyed, and other chemical changes effected. The starch granules become, for the most part, ruptured, and so intimately combined with the gluten, that they can no longer be separated as before, and a portion of the starch, especially on the outer part of the cake or loaf, is converted into dextrin. The dough loses its flabby character owing to the hardening of the gluten, while the bread becomes permanently vesiculated, and easy of mastication and digestion.

In the case of fermented bread, it is essential, in order to obtain a good result, to use good, active, sound yeast, for an unsound ferment is almost certain to cause the bread to be sodden and heavy, and probably sour and unpalatable. Great cleanliness is also a necessary precaution to be taken in preparing the dough, and the fermenting troughs should be kept in a clean and sweet condition. There are several other modes, besides the use of a ferment, of producing porous bread, which do not involve the loss of any starchy or saccharine matter. The simplest of these consists in kneading the flour with water charged with carbonic acid gas, which becomes expanded by the heat of the oven, leaving the bread on setting in a permanently porous condition. This, in substance, is the process invented by Dr. Dauglish for making what is generally known as *aërated bread.* The details are briefly as follows: Water in a strong vessel is charged with carbonic acid gas under a pressure of 150 lbs. to 180 lbs. per square inch. In another equally strong and close vessel, fitted with a

kneading apparatus, is placed the flour with a due proportion of salt. The water, charged with the gas, is then conveyed by a close pipe to the vessel containing the flour, and the kneading is effected in the apparatus under strong pressure. When the mixing is completed, the pressure is removed, and the gas thereupon causes an immediate and regular expansion of the dough with which it is incorporated. The dough still further expands by the heat of the oven, a circumstance which renders it necessary that the top crust should not be formed until the baking is nearly completed. To effect this object, special ovens are in use which bake chiefly from the bottom, the top heat being turned on only when it is necessary to form the upper crust. It is stated that by this process, 118 quartern loaves can be made from a weight of flour which by the fermentative process would only yield 105 or 106 of such loaves; but a comparison of this kind could only be of value provided an estimation was made at the time of the amount of water in each description of bread; and it is doubtful whether this was done. It is obvious, however, that there must be, to some extent, a gain in weight in making bread by aëration, although the advocates of the fermentative process allege that this gain only amounts to about one per cent., that being the amount of sugar necessary to produce sufficient carbonic acid gas to impart to the dough the requisite porosity.

In private families, porosity is sometimes produced in bread by means of bicarbonate of soda, and hydrochloric or tartaric acid, or by baking powders, which generally consist of a mixture of bicarbonate of soda, tartaric acid, and rice flour. In either case carbonic acid gas is liberated and expands the dough, but besides the general objection to the use of chemicals in the preparation of food, there are the further objections that commercial hydrochloric acid is always impure, and that the habitual use of an aperient like tartrate of soda may be injurious to some constitutions. Another, and more recently devised mode of raising dough, is to liberate carbonic acid gas within it by

means of bicarbonate of soda and the acid phosphates of lime and potash. Flour is sold containing these ingredients under the name of "self-raising flour," and its use is advocated on the ground that the ingredients added restore to the flour an amount of phosphates equivalent to the quantity of such salts removed in the bran and pollard.

Brown bread is, or ought to be, made from wheat which has been ground either entire, or with only a portion of the outer husk removed; but it is said that bakers frequently make it by simply adding a quantity of pollard or fine bran to ordinary flour. Its dark colour is not so much due to the mechanical mixture of the wheat husk with the flour, as to the action of the cerealin and other nitrogenous principles present in the husk, upon the other constituents of the flour. This has been proved by the fact that if the activity of the cerealin be first destroyed by heat, a comparatively white bread can be made from flour containing the entire constituents of wheat.

There has been much discussion from time to time upon the comparative nutritive properties of white and brown bread. On the one hand it is held that a considerable proportion of the bone-forming and other material of the wheat is removed, but on the other it is contended that there is a disadvantage in using brown bread, owing to the irritating effects produced which hinder the complete assimilation of all its nutritive properties.

Brown bread is often eaten as a laxative, while white bread, in which this property is absent, is found to be more sustaining by those who have to undergo great bodily exertion. A kind of brown bread has, however, recently been offered to the public under the name of "*wheat meal bread*," which is recommended as possessing greater nutritive properties than white, without the disadvantages of ordinary brown, bread. It is made from flour, produced by grinding wheat, deprived of a portion of its husk, between steel rollers, whereby no rough edges are left upon the particles of the husk remaining in the flour.

The various kinds of bread known as Household, Cottage, Bricks, etc., are frequently made from the same dough, and the difference in their flavour is produced by the different modes in which the heat of the oven is allowed to act upon the dough.

History.—In the earliest periods of human existence the cereals would doubtless be used as food in their natural state, and, as before stated, on page 85, it was a tradition of the Egyptians that barley was the first to be so used. It is said that the most primitive method of making bread, was to soak the grain in water and press it into cakes, which were afterwards dried in the sun. As knowledge and experience increased, modifications would be gradually introduced, such as bruising the grain in a mortar, or between stones, and partial removal of the husk before the grain was pressed and dried. The process of drying in the sun would also as gradually be superseded by artificial heat. Baking had become a trade, and bread was used both in the leavened and unleavened state, so early as the time of Moses. It is considered probable that the art of using leaven spread from the Egyptians, first to the Greeks, and afterwards to the Romans, both of which nations paid great attention to the making of bread. In the ruins of Herculaneum there were found two entire loaves similar in size, as well as bronze moulds for making bread and pastry. The Romans carried their knowledge of bread-making to many other countries, yet it is stated that so late as the middle of the sixteenth century, the only kind of bread known in Sweden and Norway was in the form of unleavened cakes. Leaven, as used in ancient times, is still employed on the Continent in districts far away from breweries, but in this country it has been almost entirely superseded by brewers' or distillers' yeast.

It is only within a comparatively recent period that wheat has held its present prominent position in the dietary of the more *civilized* portion of the human race. In olden times the cereals

principally used in Europe were barley, rye, and oats; and in the more northern countries, where the climate is unsuitable for the growth of wheat, these cereals still form a large proportion of the food of the people. In England, wheat for a long time was chiefly confined to the upper classes, but at the present day, partly from its greater nutritive properties, and partly on account of its greater suitability for bread-making purposes, it has, even amongst the very poor, entirely superseded barley and rye, and also very largely displaced oats.

CHEMICAL COMPOSITION.

The composition of bread differs in some important particulars from that of the flour or cereal from which it is prepared. These differences are partly of a physical and partly of a chemical nature. The former arise almost entirely from the application of heat in the baking, which chiefly affects some of the albuminoids by rendering them insoluble, and the starches by rupturing or bursting the envelopes and liberating their contents, which thus become easily acted upon by the digestive juices of the animal economy. The chemical changes are mainly brought about by the action of the soluble albuminoids of the grain upon the starchy matter when brought in contact with water. The change occurs in presence of cold water, but it proceeds more rapidly on elevation of temperature. In the case of leavened bread, a portion of the sugar disappears and becomes converted into alcohol and carbonic acid gas. The changes which take place in the conversion of flour into bread may be said to be strictly analogous to what occurs in the manufacture of beer, but within much narrower limits—the albumin is coagulated, the starch is partly converted into

maltose and dextrin, and a portion of the sugar decomposed into carbonic acid gas and alcohol. In a large bakery the quantity of alcohol produced must be very considerable, and this fact led at one time to the application of means for the condensation of the alcoholic vapour given off in the baking, but the expense of the recovery of the spirit proved too heavy to make the process remunerative.

We have, therefore, in bread, made either with or without yeast, all the constituents of the flour with a fresh body consisting of a new form of sugar, namely, maltose; but to this there ought to be added carbonate of soda, tartaric and hydrochloric acids, which are introduced for rendering the bread porous when yeast is not employed.

In the opinion of bakers, the presence of a small proportion of salt is essential to successful bread-making, as it is held that it causes the dough to rise better in the oven, probably by enabling the albuminous matter to set more readily, and thus preventing the inflated dough from receding before the end of the baking process. The quantity used varies with the quality of the flour, an inferior not being capable of bearing so much as a good flour.

The following table contains the results of the analyses of two loaves of aërated, and two of home-made bread, the same flour being used in the preparation of both kinds. The aërated loaves were made according to Dr. Dauglish's system, and the home-made by the usual fermentative process.

TABLE I.—CONSTITUENTS OF BREAD DRIED AT 212° F. (100° C.).

Constituents.	Aërated.				Home-made.			
	Tin Loaf.		Cob Loaf. (Paris Bread.)		Tin Loaf.		Cob Loaf.	
	Crumb.	Crust.	Crumb.	Crust.	Crumb.	Crust.	Crumb.	Crust.
Starch, dextrin, cellulose, etc.	78·93	78·96	82·75	82·82	78·12	77·62	82·05	83·42
Maltose	6·40	5·61	4·66	3·94	6·87	6·68	4·85	4·11
Albuminoids and other nitrogenous matter { insoluble in alcohol	10·30	11·28	8·58	9·09	11·65	11·17	10·59	8·68
Albuminoids and other nitrogenous matter { soluble in alcohol	1·96	1·75	1·80	1·85	1·74	2·00	1·28	2·37
Fat...	·18	·16	·13	·17	·22	1·22	·15	·39
Inorganic matter	2·23	2·24	2·08	2·13	1·40	1·31	1·08	1·03
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Percentage of moisture in the bread when new ...	44·09	19·19	41·52	16·48	42·02	22·92	41·98	20·02

A consideration of the results given in the above table affords sufficient evidence that the percentage of saccharine matter in the finished loaf is practically the same whether it has been made by the aërated or by the fermentative method. Indeed, the two kinds of fermented bread differ more, in their results in this respect, than the fermented bread does from the aërated. This throws doubt on the statement that aërated bread is sweeter than that which has been prepared with yeast; a belief which is probably based on the fact that the latter has undergone fermentation, and that consequently there must be a loss of sugar. But the quantity of saccharine matter produced in this process of bread making is so considerable, and the amount required to furnish sufficient carbonic acid gas to form a sponge is so small as scarcely to affect the relative proportion of saccharine matter in the two kinds of bread. Besides, as the dough prepared for fermented bread is naturally longer in process before the chemical action of the albuminous matter has been suspended by the application of heat, it is probable that a little more maltose is produced, and the sugar therefore lost by fermentation is fully compensated for by the greater production of saccharine matter in the fermented dough.

If the loss of sugar is as small as that indicated, the statement that several more loaves can be made out of a sack of flour by the aërated than by the fermentative process, the proportion of water being taken into account, is somewhat doubtful.

Starch.—The starch is present in bread in a swollen or gelatinized condition, in which nearly all traces of the distinctive shape and markings of the starch granules are lost. In this condition the starchy substance is readily acted upon by the soluble albuminoids of plants, and by the digestive principle of the animal organism. It has been shown that unbroken *starch granules* will remain unaffected by the active albuminoids,

as well as escape conversion into other compounds, even during the process of digestion. Hence the advantage of employing starchy matter as an article of food, after it has been subjected to the above change.

Dextrin.—As before stated, dextrin is formed simultaneously with maltose in the preparation of dough; but there is, no doubt, an additional quantity produced in the crust of the bread, along with a little caramel, from the higher temperature to which it is exposed. Dextrin is of a very gummy character, and helps to give to the bread in which it may exist in large proportion, a heavy, dark, and objectionable appearance. It is easily soluble in water, and insoluble in strong alcohol, but its separation from the saccharine matter of the bread by means of alcohol is almost impracticable.

Maltose.—Of the carbohydrates found in bread, maltose stands next to starch in importance, regard being had to the quantity in which it is present. It is most readily formed when gelatinized starch is brought into contact with an aqueous extract of germinated grain. But all the cereals in the ungerminated condition have the same kind of power, only in a less degree, of yielding an extract which will effect the change of starch into maltose and one or more forms of dextrin. The latter may be regarded as intermediate products, as their percentage composition is the same as that of the starch molecule.

The change brought about by the aid of the active albuminoids may be expressed by an equation as follows:

$$10\,C_{12}H_{20}O_{10} + 6\,H_2O = 6\,C_{12}H_{22}O_{11} + 4\,C_{12}H_{20}O_{10}.$$

Starch + Water = Maltose + Dextrin

From this formula it will be seen that maltose has the same chemical composition assigned to it as cane-sugar. It is possessed of considerable sweetness, is capable of crystallization, and directly reduces a solution of copper salt. Its copper reducing

power is nearly $\frac{62}{100}$ that of dextrose, and its specific rotary-angle + 150° for the *j* ray.

In bread made from fine wheat flour it is estimated that at least 10 per cent. of the starch is converted into maltose and dextrin; but in the case of whole-meal bread the proportion is usually much higher—the dark, heavy appearance of the latter being an indication of the presence of a higher amount of these soluble carbohydrates. This property of whole meal has been partly overcome by heating the flour before baking in order to diminish the converting power of the albuminous matter. In the fact that rye meal contains albuminoids which excel those of the other cereals in activity we have an explanation of the pasty and dark appearance of the bread made from this description of grain. The quantity of maltose produced in both aërated and fermented bread lies between 4 and 7 per cent. Bread contains about ½ a per cent. of a sugar other than maltose, which may partly consist of the sugar originally present in the flour. It is included in Table I. along with the starch, dextrin, etc.

Albuminoids.—The albuminous matters of flour undergo certain changes which do not, however, seriously affect their distinctive characters. The albumin and gluten are coagulated, and the solubility of the latter in 70 per cent. alcohol is greatly diminished, the proportion extracted by this solvent being under 2 per cent.

Fat.—It will be observed from the table that the quantity of fat obtained from the bread is very small—only about one-sixth of the quantity present in the flour. It may be that a portion of the fat is decomposed and intimately combined with some of the constituents of bread, or a more likely explanation of the peculiarity is that, owing to the coagulation of the albumin, the fat becomes locked up in the substance of the bread, so that the ether fails to extract it even though the bread is dried, finely pulverised, and repeatedly treated with the solvent.

It will be noticed also that the amount of fat in the crust

of the home-baked bread, is comparatively high; but this is due to the greasing of the tins—a common practice in domestic baking.

Ash.—The percentage of ash is greater than in flour. This is mainly due to the presence of salt which is added to the extent of from 1 to 1½ per cent. of the flour, for the purposes previously mentioned. In the case of the home-baked bread, the analysis of which has been given, the quantity of salt present appears to be less than the above; but this arises from the salt not having been added in the proportion used by bakers.

Water.—In the four loaves specified the amount of water ranged from 41·52 to 44·09 per cent. in the crumb, and from 16·48 to 22·92 per cent. in the crust. When calculated upon the entire loaf, the amount of water was 37·28 and 34·40 per cent. respectively in the aërated loaves, and 37·48 and 37·59 per cent. respectively in those baked at home.

MICROSCOPIC STRUCTURE.

The heat of the oven acting on the moist dough during the baking process causes the starch granules to swell, and in many cases to burst; and the granules that remain entire are often so modified in shape, and have their distinctive markings so obliterated, as to render their identification difficult and unsatisfactory. A microscopic examination should, however, be made, as any slight evidence that may thus be afforded of the presence of foreign starch may be confirmed by the detection of pieces of the husk or testa of the supposed adulterant.

ANALYSIS.

The methods of analysis given under the head of Flour, are generally applicable to bread, and need not here be repeated.

ADULTERATION.

The adulterants of bread are similar to those mentioned under the head of Flour, viz.—other cereal flours, starches, alum, earthy salts, etc.

Indeed, it will be obvious that bread affords even greater facilities than flour for the admixture of foreign cereal flours and starches, because the change which takes place in their condition during the process of baking, renders their detection, or at least their estimation, almost impracticable.

This arises from the effacement of the distinctive microscopic characters produced in nearly all starch granules when subjected to the heat of boiling water, a circumstance which enables the baker to add such cheap substitutes as boiled rice or potatoes in bread-making with little fear of detection. The use, however, of most of the substances named above appears to have been discontinued, rice and one or two other farinaceous products and alum being the only substances known to have been used in recent years, and from the great difficulty of proving the presence of the former, the point of greatest interest in bread analysis has come to be the determination of the quantity of added alum.

The use of rice flour in bread can only be regarded as an adulteration, as it only serves the purpose of a cheap substitute for wheat flour, without being essential to or in any degree improving the appearance or quality of the bread. It enables the baker to sell the same weight of bread at a somewhat lower rate, and with this object it is sometimes added in bread-making in poor neighbourhoods where the offer of a cheaper loaf encourages the sale of such bread. Owing to the lower price charged, it can scarcely be said that any serious advantage is taken of the purchaser, for it would probably be found that the reduction in price is nearly in proportion to the quantity of cheaper materials used.

The addition of potatoes in a boiled and mashed condition

is almost universally made in bakeries wherever the fermentative process of bread-making is followed.

Considering the small proportion of potatoes generally used—less than 1 per cent. of the dry substance—the intention can hardly be said to be that of adding weight to the bread. The object appears to be to cause a more rapid production of saccharine matter by the action of the albuminoids of the flour on the gelatinised starch of the potato—a result which will favour a quicker fermentation, and the production of the necessary carbonic acid gas to form the sponge.

Bean or pea flour would only be employed on account of its cheapness, and would add to, rather than detract from, the nutritive properties of the bread; though if used in considerable proportions, there is a danger of imparting an unpleasant flavour to the bread.

As pure wheat flour has been found to contain a quantity of alumina equivalent to from 2 to upwards of 40 grains of ammonia alum per 4 lbs., the addition of rice or potatoes to flour would not increase the proportion of alumina. This will be seen from the analysis of rice on page 88, which is shown to be free from alumina, and from the following results obtained from the analyses of four samples of potatoes which had been peeled and boiled in the usual way:

TABLE II.—ANALYSES OF POTATOES.

No.	Percentage of Water.	On the Potatoes dried at 212° F. (100° C.			
		Percentage of Ash.	Per 4 lbs.		
			Silica.	Phosphate of Alumina.	Equivalent Ammonia Alum
1	78·99	3·48	2·37	1·90	7·03
2	78·77	4·48	3·29	·94	3·48
3	75·16	3·98	3·15	1·80	6·66
4	73·75	2·64	1·70	1·28	4·73

The principal adulterant of bread at the present time is alum. This substance has the property of increasing the porosity of bread, and giving to it an appearance of whiteness which it would not otherwise possess. It seems probable that the alum, owing to its astringent character, acts on the gluten, and renders it more tenacious, so that when the baking process is complete, the bread is found lighter and more porous.

Some hold the opinion that the appearance of greater whiteness is not due to any chemical action on the colouring matter of the flour, but to an optical effect, arising from increased porosity in the bread, which is brought about by the use of alum. There is little doubt, however, that alum diminishes any tendency to excessive production of maltose and dextrin, and the consequent heaviness of the bread, a condition very noticeable in that made from whole wheat flour, is thereby avoided; and this is especially the case where an inferior or partly damaged flour has been used.

Considerable difference of opinion exists as to whether bread made from alumed flour is injurious to health. Those who regard the presence of alum as harmless, rely partly on the smallness of the quantity generally present—less than 50 grains in the 4-lb. loaf—a proportion which is supposed to be too small to affect the animal system, and partly on the statement that, as it cannot be extracted from the bread by water, the alumina exists in an insoluble condition, and presumably remains inert.

For the opposite view, experiments are cited in which animals have been fed with alumed food with the marked effect of retarding digestion. It is also stated that when gluten containing a little salt of alumina—either phosphate of alumina or alum—is acted on by artificial gastric juice the solution of the gluten is retarded.

Whichever view is held, there can be little difference of opinion that the safest course to adopt is to regard the addition *of alum as* unnecessary in the process of baking, and that when

it is found its presence should be dealt with as a clear case of adulteration. Alum is not added to bread to improve its fitness as food, but simply to lead the public to infer from its whiteness and general appearance that the bread has been made from a better description of flour than has really been the case.

The principal methods for the detection and estimation of alum have been given under the head of Flour; but the logwood test, when applied to bread, is varied as follows: To about a wine-glassful of water in a porcelain capsule, 5 cubic centimetres of freshly prepared tincture of logwood, and the same quantity of the carbonate of ammonia solution are added. A piece of the crumb of the bread, say about 10 grams, is then soaked therein for about five minutes, after which the liquid is poured away, and the bread is dried at a gentle heat. If alum be present, the bread will acquire a lavender colour or more or less approaching dark blue, according to the quantity of alum which has been added; whereas if the colour be a dirty brown, the bread may be regarded as pure, and, unless under special circumstances, the quantitative estimation of the alumina need not, as already mentioned, be undertaken.

As stated on page 111, the test is rather negative than positive, and should a lavender or blue colour be produced, a quantitative estimation of the total alumina and silica will be necessary.

Although the reliability of the logwood test was for a time doubted by some analysts it has since grown in favour, and is now generally regarded with confidence. This has in great part arisen from the importance attaching to any test which will act as an indicator of the presence of soluble salts of alumina, as it is now well known that both flour and bread often contain a considerable quantity of aluminic compounds without any alum having been added.

Earthy salts—such as carbonate of lime or chalk, carbonate of magnesia, sulphate of lime or gypsum, and silicate of magnesia or soapstone—would only be added to give weight. Their presence

will be readily indicated by an excessive percentage of ash, and their identification effected by the chemical tests applicable to each substance, and referred to under the head of Flour.

The addition of such compounds to bread may properly be regarded as a question belonging to past years, for there is no instance on record of any of them having been recently discovered in bread.

Sulphate of copper is said to have been occasionally used in this country and on the Continent to improve the colour of bread; and although there are no good grounds for believing that the practice exists at the present time, it may be well to point out a means by which so deleterious an adulterant may be detected and estimated.

As a preliminary test, a portion of the crumb of the bread should be soaked in a dilute solution of ferrocyanide of potassium acidified with acetic acid, when, if sulphate of copper has been used, the bread will become of a reddish-brown colour according to the quantity of copper present. To estimate the copper 100 to 150 grams of the bread are moistened with dilute sulphuric acid, and charred over an Argand lamp or in a muffle. The charred mass is digested with water, the extract filtered off, and the residue, after the addition of a few drops of sulphuric acid, dried and thoroughly ignited.

The ash, if much copper be present, will be found of a pale green colour. The first filtrate, made slightly acid, is now added to the ash, and after digestion for some time, the extract, which will contain all the copper, is separated by filtration.

If any great excess of acid be present, the solution may be neutralised with ammonia, and again made faintly acid with sulphuric acid. The liquid is then introduced into a lipped platinum capsule, in which the copper salt is decomposed by an electric current from a single Grove cell, care being taken, however, to insulate the platinum capsule by placing it on a glass plate. The copper may either be precipitated on the

inside of the capsule or upon a slip of platinum foil of known weight, according to whichever surface is rendered negative by being connected with the opposite pole of the battery. After about two hours, or when a distinct deposit of copper has been formed, the mother liquor is poured off, and the platinum vessel rapidly washed with cold distilled water, which had been previously well boiled. The platinum, with its deposit of copper, may be dried in a current of hydrogen or carbonic acid gas, but no appreciable oxidation has been observed when the drying was carried out in an ordinary closed water-bath. The platinum capsule or foil is then carefully weighed, and the previously ascertained tare deducted. The difference is the weight of metallic copper, from which the weight of sulphate of copper, if necessary, can be calculated. The mother liquor is again submitted to the action of the electric current, and if any further deposit of copper occurs, its weight must be ascertained as before.

The process is also applicable to the analysis of tinned vegetables, bottled fruits, or other articles of food liable to admixture with copper. With tinned foods care must be taken to remove the platinum from the electric current as soon as the discoloration of the metallic deposit affords evidence of contamination with lead or tin.

Cones Flour.—This name was originally given to flour prepared from a coarse variety of wheat called revet. The flour, which was a cheap description, was used for dusting the dough and boards on which the bread was kneaded to prevent adhesion and facilitate the making of the loaves.

The article now used as cones generally consists of rice or maize flour, or of a mixture of both, and it rarely contains a particle of wheat flour. The substitution of rice and maize for wheat flour is a question of cheapness, and so long as the use of the article is confined to the original purpose of "cones," and

is not introduced into the composition of the loaf, there is not much to object to in the use of the lower-priced article, especially when we consider that, being less glutinous than wheat flour, it may give greater facilities in working the dough than the latter, and also that, in the process of baking, a considerable loss of the cones flour must take place.

OATMEAL.

Botanical Origin.—Oatmeal is prepared from oats, which are derived from a genus of plants called *Avena*, belonging to the same natural order as wheat. There are two commonly recognised species of the oat, *Avena sativa* and *Avena orientalis;* but there are several varieties, especially of the former, such as the bearded or long black oat, the white, red, and naked oat. The best variety cultivated in this country is said to be the potato oat, which, being large, firm, and plump, commands a high price, and is consequently in greatest favour with agriculturists.

Oats grow better in cool moist climates than in those which are hot and dry, and consequently have the advantage of being capable of cultivation upon soils and in situations where neither barley nor wheat can be raised.

Oats differ from wheat, barley, and rye in the form of the ear, which in the case of the oat is a panicle. This in some varieties is contracted, with the peduncles all turned on one side, while in others the branches of the panicle, which become smaller towards the head, form a tapering or conical figure. Each subdivision of the panicle is terminated by a brittle pericarp containing the seed

or oat, and as this develops in size, the vertical position is lost, and the head takes the form of a series of drooping branches.

Description.—Oats as met with in commerce, consist of the seeds enclosed in their husk or outer skin. Before they are ground into meal they are kiln-dried, and the husks removed. Scotch oatmeal is generally more coarsely ground than English, but the degrees of fineness of both vary according to the prevailing taste in different localities. The meal is much less white than wheat flour, and has a peculiar, almost bitter, taste. It is chiefly eaten in the form of porridge and oat cakes. Owing to the absence of gluten, oatmeal cannot, like wheat flour, be made into light porous bread. It is devoid of that tenacity or adhesiveness when made into a paste, which is essential for holding the vesicles of gas, and for producing the requisite porosity, or lightness, in the mass.

History.—The native country of the oat has not been decided with certainty, but it is supposed from its hardy character to have had its origin in a more northern latitude than any of the other cereals. The particular date at which it was first introduced into England is unknown, but the plant has been claimed as indigenous to this country, and the wild oat is certainly so. There is evidence that the inhabitants were possessed of oats in the year 1296, and mention is made of the use of oatmeal porridge as an article of food in 1596.

In the year 1698, the consumption of oatmeal was estimated as only second to barley, and as considerably greater than that of wheat; but during the early part of the last century the consumption of oatmeal in England and Wales largely decreased, and its place was taken by wheat, which had become much more generally used as an article of food by the common people.

In several parts of the kingdom, and especially in Scotland, oatmeal still forms a valuable and important food for the people, and it admittedly produces a healthy and vigorous race of men.

CHEMICAL COMPOSITION.

The chemical constituents of oats are similar to those of wheat, but as will be seen from the table on page 86, they vary in the proportions in which they are present. The proportion of nitrogenous matter bears a favourable comparison with that of the other cereals, but oats stand lowest as regards the amount of starch.

The proximate analysis of a sample of oatmeal gave the following results:

TABLE I.—OATMEAL (SCOTCH).

Fat	7·74
Starch	59·88
Sugar	1·27
Albumin insoluble in Alcohol ...	15·66
Do. soluble ,, ...	4·21
Cellulose	2·05
Mineral Matter...	1·94
Moisture	7·25
Total	100·00

The following table contains the results of the analysis of the ash or mineral matter:

TABLE II.—ANALYSIS OF THE ASH OF OATMEAL.

Constituents.		
Potash	estimated as K_2O	11·46
Soda	,, ,, Na_2O	·83
Sodium Chloride ...	,, ,, NaCl	2·07
Magnesia	,, ,, MgO	11·92
Lime	,, ,, CaO	3·50
Oxide of Iron ...	,, ,, FeO	1·42
Alumina	,, ,, Al_2O_3	Trace
Oxide of Manganese	,, ,, Mn_3O_4	Trace
Phosphoric Anhydride	,, ,, P_2O_5	61·14
Sulphuric ,,	,, ,, SO_3	·92
Silica...	,, ,, SiO_2	4·28
Sand	... ...	2·46
Total		100·00

These constituents correspond very closely with those found in *the ash of* wheat flour.

MICROSCOPIC STRUCTURE.

The microscopic appearance of the tissues composing the husk or outer covering of the oat is shown in Fig. 17. The outside membrane is composed of long narrow cells, with well-

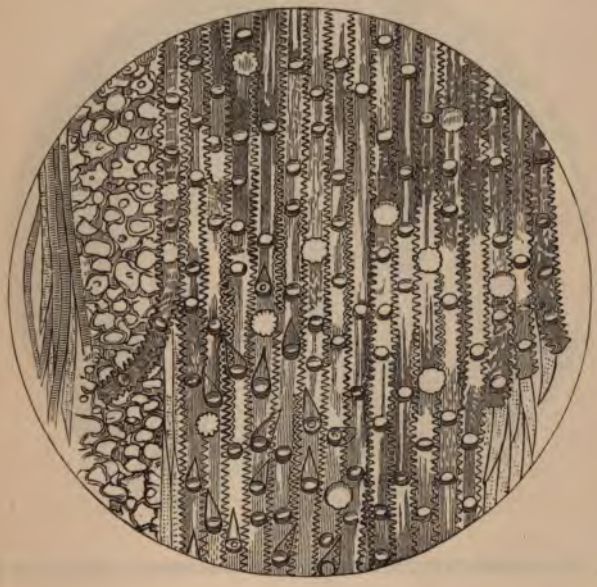

FIG. 17.—HUSK, OR OUTER COVERING OF OAT. MAGNIFIED 100 DIAMETERS.

marked serrated edges, and contains small round flattened discs of silica. Immediately underneath this tissue there occur rows of spiral vessels and long thin woody cells with pointed ends. Attached to the outer membrane are numerous short, pointed, spinous hairs.

The inner covering or integument consists of four tissues, as exhibited in Fig. 18. The first membrane consists of elongated cells, with straight walls. The second, to which are attached, at one end, numerous long, pointed hairs, is formed of elongated

FIG. 18.—INNER INTEGUMENT OF OAT. MAGNIFIED 100 DIAMETERS.

cells, with faintly-beaded edges. The third is composed of long, irregularly-formed cells, lying in a wavy form. The fourth is a comparatively thick tissue, made up of oval and rounded cells, filled with granular matter.

The starch granules of oatmeal are smaller than those of wheat. They vary in size from ·0001 to ·0004 of an inch in diameter, are polygonal in form, and only the larger granules exhibit a hilum. The appearance of oat starch is shown below in Fig. 19.

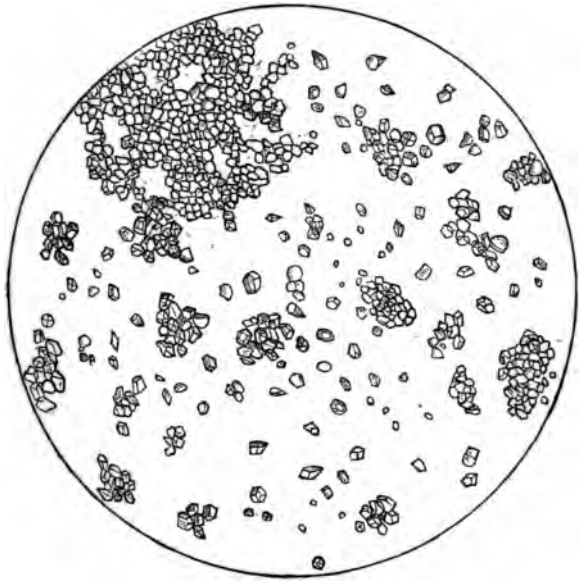

FIG. 19.—OAT STARCH. MAGNIFIED 350 DIAMETERS.

ADULTERATION.

The only adulterant which in recent years has been discovered in oatmeal is barley meal, but it is said that at one time other adulterants were used, such as rice and maize flour, and the ground husks of the cereals.

The presence of barley meal is readily detected by the microscope from the character of the starch granules. The appearance of these under the microscope will be seen on page 118, Fig. 11. In the examination of a sample of oatmeal it is important to be careful to discriminate between barley meal starch and the aggregated masses which occur in the granules of oatmeal starch. It is a property of oatmeal for a number of the starch granules to adhere to each other in such a manner as to form round or oval bodies, about the size of the larger granules of barley starch, for which they are sometimes mistaken.

The presence of rice or maize flour can, like barley meal, be detected by the microscope from the character of the starch granules. The appearance of rice starch will be seen on page 121, Fig. 14, and that of maize starch on page 173, Fig. 29.

The mode in which the amount of foreign starch is conveniently estimated is described on page 151.

There has been no instance in which ground husks of cereals have been detected as an adulterant of oatmeal since the present Adulteration Act came into operation; but such an article is a possible adulterant, and the microscopical examination of a suspected sample should include a search for the presence of an admixture of cereal husks, which, however finely ground, are comparatively easy of identification from the structure of the tissues. The tissues of oat husk are shown in Figs. 17 and 18, those of wheat husk on page 104, Fig. 7, and those of barley husk on page 117, Figs. 9 and 10.

PREPARED STARCHES.

THESE preparations, which consist of purified starches, differ in a most essential degree from cereal flour, in that, when used alone, they are an incomplete food, and require to be conjoined with other alimentary matter, containing flesh and bone-forming materials. Starch contributes only towards force and fat production, and although its deficiency as a means of nourishment is now well understood, there is too much reason to believe that it is often resorted to as a food for the young, to an extent frequently attended with serious injury to health.

The source of these preparations is not restricted to cereals, as the tubers of many plants and the stems of some trees yield different kinds of starch in great abundance, and one or other of them is used as an article of food by all nations.

As each description of starch yields a flavour peculiar to itself, there probably exists in it a minute quantity of essential oil, which imparts a character to it; for chemically the starch substance is alike in each kind.

Under the microscope the starch granule is seen to have an organised structure. It consists of a thin envelope or sac, composed of cellulose, filled with a true starch substance or granulose. The latter would seem to exist in the form of layers or films, varying in thickness and probably also in density, and

starting from a point called the hilum. These layers give rise to the appearance of lines or rings on the outer surface of the granule, and sometimes, from their character, assist in the identification of a starch.

The starches derived from different sources have nearly in every case distinctive features as regards form, size, and peculiarity of marking, which afford means for their recognition by the microscope.

The envelope or enclosing membrane, which possesses a considerable amount of hardness and tenacity, retards, if not entirely prevents, the action of those soluble and active albuminoids, which effect the conversion of the starch substance into dextrin and maltose; and in like manner and from the same cause, starch, when taken as food in the raw state, resists to a certain extent the saccharizing action of the digestive juices, and many granules pass through the system unaffected. It becomes, therefore, necessary, in order to effect the before-mentioned conversion, to rupture the granules by the application of heat, so as to bring their contents under the immediate action of the soluble albuminoids or digestive juices, as the case may be. It follows that it is essential that starch foods, before being consumed, should be cooked or heated to a point sufficient to rupture the granules.

The formula $C_{12}H_{20}O_{10}$ is assigned to all starch from whatever source derived. Starch itself is insoluble in cold water, but the contents of the granules are soluble.

The temperature at which the different starches gelatinize varies from 113° F. (45° C.) to 194° F. (90° C.). Those having the largest granules rupture at lower temperatures than those with small granules such as rice and maize, which are not affected until the maximum temperature of the range indicated is nearly reached.

Iodine combines with starch, producing a deep blue coloration. This reaction takes place between the contents of the

starch granules and the iodine only, the envelope, which is composed of cellulose, giving no coloration.

Soluble starch rotates a ray of polarized light to the right, the rotatory power being $[a]_j + 216°$.

The proportion in which one starch or flour is mixed with another requires to be estimated by means of the microscope. To insure the homogeneousness of the sample it is first rubbed in a mortar, and passed several times through a sieve. A small quantity, say ·05 of a grain, is then weighed out and placed upon a glass slide, where it is worked into a thin paste with about two drops of water. A thin covering glass, measuring about 1½ inch by 1 inch, is then placed over the paste, and moved about the slide until the paste is equally distributed and all under the covering glass. With a ¼-inch objective and B eyepiece the number of granules of foreign starch is counted in nine "fields," as fairly as possible representing the entire slide. The process is repeated until a correct idea of the composition of the sample is obtained.

Standard mixtures approximately representing the sample are then made up and treated in exactly the same way, and, from a comparison of the results, the percentage of foreign starch is computed.

When the percentage of foreign starch is large it is advantageous, in order to facilitate the counting of the granules, to insert in the eyepiece a slide, accurately divided into squares.

In cases where the granules of added starch are so small and numerous that it is impossible to count them, as with rice starch, a similar process of preparing the slides is followed, and as correct an estimate of the foreign starch is made as is possible by a comparison of the appearance of the sample with that of the standard mixtures.

It is often advisable to use a dilute solution of iodine instead of water in preparing the slides for examination, as the resulting coloration of the starch granules renders them more distinctly visible.

ARROWROOT.

Botanical Origin.—Arrowroot is derived from plants of the genus *Maranta*, belonging to the natural order *Marantaceæ*. The most important member of the genus is *Maranta arundinacea*, which is a native of the West India Islands and of the tropical parts of America, but is now cultivated in Africa, Ceylon, and other hot countries. There are three other recognised species of *Maranta*, namely, *M. allouyia* and *M. nobilis*, which grow in the West Indies, and *M. ramosissima*, which is a native of the East Indies.

The arrowroot plant is herbaceous, from four to six feet high, and has broad, pointed leaves. The tuberous roots, or rhizomes, are pointed, covered with scales, and sometimes a foot in length, and about the thickness of a finger.

Description.—The starch is stored in the rhizomes of the plant, and requires to be extracted and purified to render it fit for the market.

When the plant is mature, which it generally is at the end of twelve months from the time of planting out, the rhizomes are dug up, washed, peeled, and reduced to a pulp by crushing or rasping. The pulp is then washed with water on a sieve or in a washing machine, constructed for the purpose. The fibrous matter is thus separated from the starch, which passes through the sieve with the water, and gradually forms a deposit in the tanks or vessels in which the liquid is collected. The starch which subsides, being somewhat impure, is repeatedly washed until thoroughly purified, after which it is drained and then dried either in the sun or by gentle artificial heat. The rhizomes yield, when they contain their maximum amount, about 26 per cent. of starch.

Every care is taken in the process of preparation to insure purity, and owing to the reputation for this quality, which the

arrowroot prepared in Bermuda has obtained, it commands a much higher price than that made either in other West India Islands or elsewhere. From improved modes of preparation, however, much of the low-priced arrowroot now imported, and notably that from the Island of St. Vincent, is undistinguishable in any respect from the higher-priced article from Bermuda. The quality and commercial value of an arrowroot chiefly depend upon its brilliancy and whiteness, and for a long time, that from Bermuda maintained a distinct pre-eminence in this respect.

For trade purposes arrowroot is distinguished by the name of the island or country producing it. Thus we have Bermuda, St. Vincent, Natal, Cape, and Mauritius arrowroots, although they all consist of the same kind of starch, and are derived from the genus *Maranta.*

The imports from Bermuda, which no doubt at one time were our chief supply, have been decreasing for several years, and the great bulk of the arrowroot now imported comes from St. Vincent and Natal.

Arrowroot is much appreciated as an article of food for invalids, but its alimentary value is limited to that which belongs to pure starch, and it therefore requires to be supplemented by food of a nitrogenous character.

History.—The earliest recorded notice of the plant *Maranta arundinacea* relates to the supposed virtue possessed by its roots as an antidote to poisoned arrows, and it is generally agreed that the term arrowroot owes its origin to a belief in the efficacy of the plant in this respect by the Indians of South America.

It would appear, from a catalogue of Jamaica plants prepared in 1696 by Sloane, that the *Maranta* was first discovered in Dominica; from thence it was transferred to Barbadoes, and afterwards to Jamaica, the plant being much esteemed on account of its reputed power of counteracting the effects of poison.

In the year 1756 mention is first made of the starch of the

plant as an article of food, but its use was limited to periods when other provisions were scarce.

Arrowroot was first introduced into England about the beginning of the present century, and it appears that the supplies came from Jamaica. It was subject to an import duty, which, prior to 1853, amounted to 6*d.* per cwt. on that imported from British possessions, and 2*s.* 6*d.* per cwt. on that brought from other countries, but in the year named a uniform rate of 4½*d.* per cwt. was imposed, which continued until 1869, when the article was admitted free of duty.

In 1850 the imports of arrowroot into the United Kingdom amounted to 15,980 cwts., of which 12,631 cwts. were entered for home consumption; and in 1870 the quantity imported was 21,770 cwts., and of this 17,000 cwts. were from St. Vincent, and 3,000 cwts. from Natal; but for some time past the importations of arrowroot have been on the decline. This is probably due to an increasing substitution for arrowroot of certain proprietary articles, many of which are sold under the name of "corn-flour." These preparations consist generally of a purified cereal starch which answers the same purpose as arrowroot, and possesses a similar alimentary value.

CHEMICAL COMPOSITION.

Arrowroot consists practically of starch and water, and therefore when pure is a non-nitrogenous substance, and is destitute of bone-forming material.

The following are the results of the analyses of the two principal commercial varieties of arrowroot:

	Bermuda.	St. Vincent.
Starch ...	83·66	84·35
Water ...	16·22	15·44
Mineral matter	·12	·21
Total ...	100·00	100·00

MICROSCOPIC APPEARANCE.

Arrowroot being a pure starch consists entirely of a mass of granules, which readily separate from each other on the microscopic slide. The granules of the arrowroot obtained from the different islands and places producing it are not identical in size and form, but they present certain characteristic features which serve to identify them as all belonging to the same genus of plants.

Bermuda arrowroot may be taken as the most perfect type of a *Maranta* starch. In no other kind of arrowroot do the granules so generally exhibit an irregularly oval form with the peculiar small nipplelike projection near one end. The microscopic appearance of this starch is represented in Fig. 20.

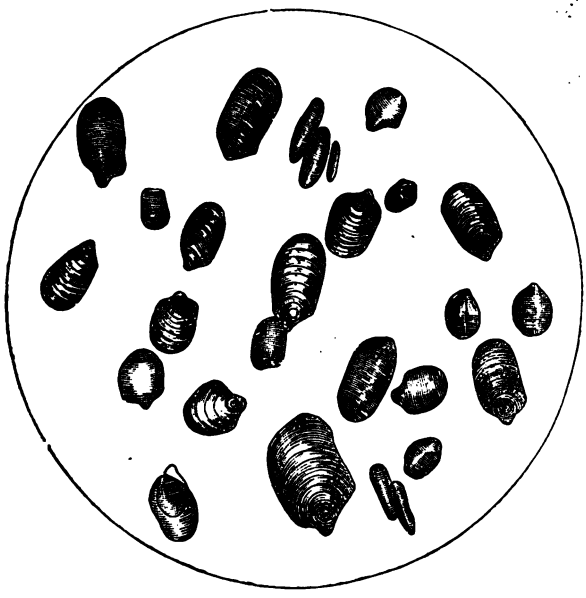

FIG. 20.—BERMUDA ARROWROOT. MAGNIFIED 350 DIAMETERS.

The granules, it will be seen, are generally marked with numerous faint concentric rings showing distinct layers, and have a circular or linear hilum near one end. The majority of the granules are fairly uniform in size, and measure from ·0007 to ·0023 of an inch in length, and from ·0005 to ·0014 in breadth.

The arrowroot from Natal, as compared with that from

FIG. 21.—NATAL ARROWROOT. MAGNIFIED 350 DIAMETERS.

Bermuda, may be taken as an example of the divergence which occurs in the form, size, and general appearance of the starch granules yielded by different varieties of the *Maranta* plant. The starch granules of Natal arrowroot are represented in Fig. 21.

In size they vary from ·001 to ·0022 of an inch in length, and from ·0005 to ·0015 in breadth.

ADULTERATION.

When the high price at which arrowroot was sold for many years is considered, it is not surprising that its adulteration should have been largely practised, nor that a variety of imitations, consisting of cheaper purified starches from other sources, should have been substituted and sold under that name. The inducement for the sophistication of arrowroot is much less now than it was formerly; but judging from the cases of adulteration which have come under our observation during the last few years, it is clear that the margin between the price of *Maranta* and that of other starches is still sufficient to make it answer the purpose of the trade to substitute, either wholly or partially, the latter for the former; and as arrowroot affords great facilities for sophistication, the danger of such a practice being continued will exist so long as the great difference of price between the best arrowroot and the cheaper starches is maintained.

The principal starches which have been employed either as substitutes for arrowroot or for mixing therewith, have been those of potato, sago, tapioca, curcuma, and tous-les-mois. Tacca and arum starches are stated to have been used as substitutes, but they are not known at present in the English market.

It is impracticable to distinguish, either by simple inspection or by any reliable chemical process, *Maranta* from any other starch. It is only possible to do this with certainty by the aid of the microscope, but with the assistance of this instrument, combined with an accurate knowledge of the microscopic appearances of the cereal and other commercial starches, the recognition either of spurious arrowroot or of a mixture of other starches with that of *Maranta* becomes, in nearly all cases, comparatively easy.

The following and other drawings of starches in different parts of this work may prove useful in the microscopic examination of suspected samples of arrowroot:

Potato Starch.—This starch is prepared from the tubers of the potato (*Solanum tuberosum*) by a process similar to that adopted in the case of arrowroot. In trade it is known as *potato flour* or *farina*.

The granules of potato starch, as seen under the microscope, are represented in Fig. 22. They vary much in form, some being triangular or oyster-shaped, some ovate, and others, especially the smaller ones, spherical. They are marked with distinct

FIG. 22.—POTATO STARCH. MAGNIFIED 250 DIAMETERS.

concentric rings, and have a hilum at one end, which is circular or stellate.

In size they vary from ·0005 to ·0028 of an inch in length, and from ·0004 to ·0017 in breadth.

Sago and Tapioca Starches.—A full description of these starches will be found on pages 166 and 170.

Curcuma Starch.—The principal source of this starch is the

tuberous root of *Curcuma angustifolia*, a plant which is a native of the East Indies. The prepared starch is called by the natives *Tickhar*, and sometimes, by Europeans, East India arrowroot. The article is said to be rather extensively manufactured in Travancore, Cochin, and in Canara in the south-west of India, and it is probable that it formed a portion of the East India arrowroot which used to be met with in the English market.

FIG. 23.—CURCUMA STARCH. MAGNIFIED 350 DIAMETERS.

The microscopic appearance of *Curcuma* starch is represented in Fig. 23. There is a considerable resemblance between the granules of this starch and those of *Maranta*; but the former are more irregular in size and shape, and also more pointed and transparent.

In size, they vary from ·001 to ·0027 of an inch in length, and from ·0007 to ·0015 in breadth.

Tous-les-mois Starch. — This starch is extracted from the rhizomes of a plant of the genus *Canna*, which is chiefly cultivated in St. Kitts, one of the West India Islands. That which is imported into this country is used partly in the manufacture of prepared cocoas, and partly, after being bleached, as food for infants. The appearance of this starch under the microscope is shown in Fig. 24.

FIG. 24.—TOUS-LES-MOIS STARCH. MAGNIFIED 350 DIAMETERS.

The granules of this starch are the largest known. They are ovate in form, obtuse at one end and pointed at the other. The hilum is circular and situated near the pointed extremity, and it forms the centre from which the well-marked series of rings originate. In size they vary from ·0015 to ·0037 of an inch in *length* and from ·001 to ·0027 in breadth.

Tacca Starch.—This starch is prepared from the tuberous roots of *Tacca oceanica*. The plant, which is herbaceous, is cultivated in the South Sea Islands for the sake of its starch.

We have been unable to meet with a sample of this starch in the market, and probably it is not now imported. Its microscopic appearance is shown in Fig. 25.

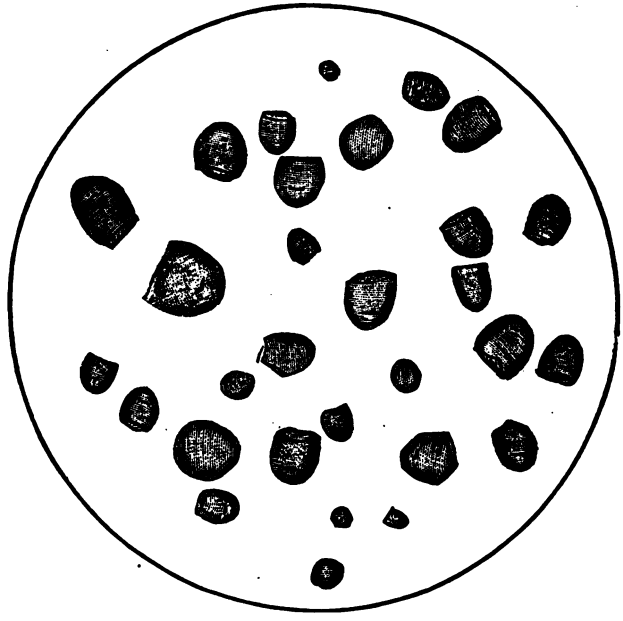

FIG. 25.—TACCA STARCH. MAGNIFIED 350 DIAMETERS.

The granules are generally very similar to those of tapioca; but some, especially the spherical ones, are larger in size. They vary from ·0012 to ·0015 of an inch in length, and from ·0008 to ·0012 in breadth.

Arum Starch.—This starch is obtained from the tubers of *Arum maculatum*. The plant, which is popularly known as "lords and ladies," was formerly cultivated in the Island of Portland.

The starch, which at one time was known as "Portland arrowroot," is not now met with in the market; but as it is said

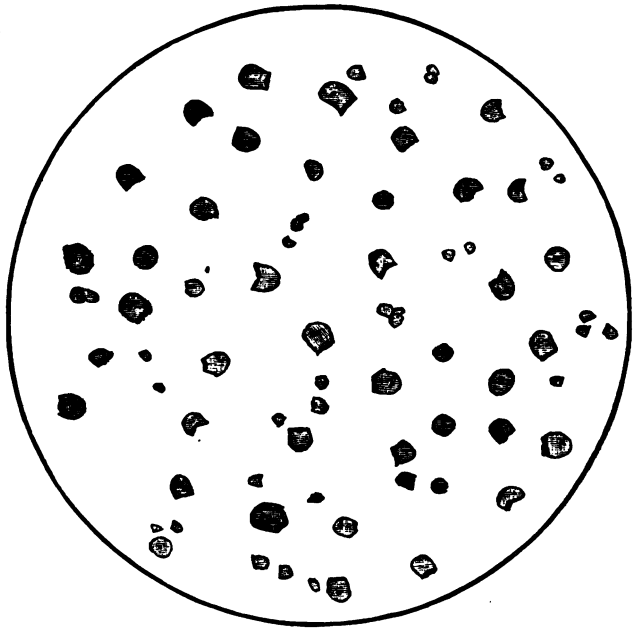

FIG. 26.—ARUM STARCH. MAGNIFIED 350 DIAMETERS.

to have been formerly used as a substitute for *Maranta*, it may be interesting to give a drawing of it. This is shown in Fig. 26.

The granules vary in size from ·0002 to ·0005 of an inch in length, and from ·0002 to ·0004 in breadth.

SAGO.

Botanical Origin.—Sago is obtained from the pith or central part of the stems of several species of palm, the principal of which are *Sagus farinifera* and *S. Rumphii.*

The sago palm grows naturally in the south-east of Asia and the islands of the Indian Ocean, and consequently requires no cultivation. The tree is somewhat peculiar, and slow in making a start; but once the stem is fairly formed, its growth proceeds rapidly until it attains a height which is sometimes as much as 30 feet, with a stem measuring 5 or 6 feet in circumference. The trunk consists essentially of a long hard woody tube, the interior of which is filled with starch, intermixed with fibrous matter.

When the tree is cut down the root retains its vegetative power, and a fresh stem is soon formed, which takes the place of the parent one.

Sago is also produced by plants of the genus *Cycas*, belonging to the natural order *Cycadaceæ*. The principal of these are *Cycas circinalis* and *C. revoluta*, which are indigenous to the Moluccas, China, and Japan.

Description.—Sago starch exists in the pith of the palm in an impure state, and requires to be submitted to a process of purification, in order to separate the fibrous and other foreign matters present.

When the tree has attained maturity, and contains its full complement of starch, it is cut down near the root, and divided into lengths of 6 or 7 feet, which are split down lengthwise, to gain access to the central part of the stem. The pith is then scooped out, reduced to a powder, and worked up with water in a trough, until the starch has been detached from the fibrous matter. The water containing the suspended starch is

then run through a sieve, and from the strained liquid a deposit of starch takes place, which, after repeated washings with water and subsequent drying, forms the sago flour of commerce.

It is stated that the produce of a single tree sometimes amounts to between 500 lbs. and 600 lbs. of sago.

Granulated sago is prepared from sago-flour by mixing it with water into a paste, and granulating it with the aid of sieves, by a process not known to Europeans. The sago in the granular form is then dried in shallow pans, with agitation, over a slow fire, and the resulting product constitutes the pearl sago met with in commerce.

There are two sorts of pearl sago imported, one consisting of small and the other of large grains. In both kinds a large proportion of the starch granules are burst, and the grains are chiefly composed of gelatinized starch.

Sago constitutes an important article of food in different parts of the East, and especially in those countries where it is a natural product. In this country granulated sago is chiefly used in the form of pudding, and like many other pure starchy preparations, constitutes a valuable light food.

The great bulk, however, of the sago imported into this country is in the form of sago flour, and is largely used in the manufacture of glucose sugar and household starch.

History.—There is no evidence to show when the starch of the sago palm was first used as a food. In the thirteenth century the preparation of sago bread was described by Marco Polo, and in the early part of the seventeenth century by Clusius. Granulated sago appears to have been known about this time, as it is said to have been introduced into England in the year 1729, and into France and Germany about fifteen years later.

The quantity of sago imported into this country has been gradually increasing, and in the year 1880 it amounted to *381,668* cwts.

CHEMICAL COMPOSITION.

Sago is composed of starch, a little mineral matter, and a certain amount of water. A sample of pearl sago gave, on analysis, the following results:

Starch	...	84·64
Water	...	15·22
Mineral matter		·14
Total ...	...	100·00

MICROSCOPIC APPEARANCE.

The microscopic appearance of sago starch is shown in Fig. 27.

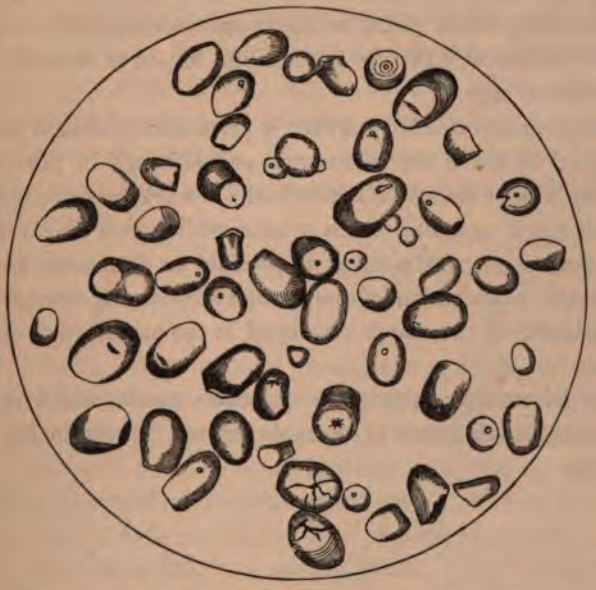

FIG. 27.—SAGO STARCH. MAGNIFIED 350 DIAMETERS.

The granules, it will be seen, are elongated, rounded at one end and truncated at the other. The larger ones have a stellate

or linear hilum, and have numerous concentric rings, which are but faintly visible. In size they range from ·0009 to ·0022 of an inch in length, and from ·0007 to ·0014 in breadth.

ADULTERATION.

Sago has never been subject to much adulteration, but there is reason to believe that potato starch was used some years ago for the production of a spurious article.

Whatever inducements there may, at one time, have been for the sophistication of sago, it is obvious that, having regard to its present marketable value, there would be a difficulty in finding another starch which could be advantageously employed, on the score of cheapness, either as a substitute for, or as an adulterant of, granulated sago.

The presence of other starches in preparations of sago can be recognised by aid of the microscope, and although in pearl sago the great bulk of the starch is practically in a gelatinous condition, and the starch granules, which remain entire, form only a small proportion of the whole, yet it is possible to determine, from a microscopic examination of the granules remaining unruptured, the character of the starch employed in the manufacture of the article.

The microscopic appearance of potato starch, which is the most probable adulterant to be employed, will be seen in Fig. 22, page 159.

TAPIOCA.

Botanical Origin.—This starchy preparation is derived from several species of plants of the genus *Manihot*, belonging to the natural order *Euphorbiaceæ*. The most important of these plants is *Manihot utilissima*, formerly known as *Jatropha Manihot*, a native of tropical America, but now cultivated in Africa and other hot countries. Another species from which tapioca is obtained is *Manihot aipi*, which constitutes what is popularly called *sweet cassava*, while the former variety is called *bitter cassava*.

The plants, which are propagated by cuttings, grow in the form of a bush to the height of five or six feet. The collateral fibres of the roots develop into farinaceous tubers, which are generally in a fit state to be collected within eight or nine months from the time of planting. The tubers occur in clusters of from three to eight, and the quantity sometimes produced by a plant weighs as much as 30 lbs.

Description.—The tuberous roots are large and fleshy, and are generally about 14 or 15 inches long, and from 4 to 5 inches thick.

To obtain the farinaceous products, the tubers are washed, scraped or peeled, and reduced to a pulp by rasping or grinding. The pulp is then subjected to pressure to express the juice, and the compressed residue, which consists of a mixture of farina, vegetable fibre, and albuminous matter, is used for making cassava meal or bread, while the juice, which is allowed to stand at rest for a time, yields a deposit of cassava starch. This, when properly washed and dried by the heat of the sun, constitutes the tapioca flour, or Brazilian arrowroot of commerce.

Tapioca is prepared by heating the cassava starch, in a partially dried state, upon hot plates and stirring it with an iron

rod. During this process a large portion of the granules burst and adhere together in small irregular masses or nodules, in which form the article is imported into this country.

Both the bitter and sweet cassava, in common with other plants belonging to the same natural order, contain a milky juice, which, in the bitter variety, is poisonous and acrid, but is innocuous in the sweet species. The poisonous quality of the juice of the bitter cassava is due to the presence of hydrocyanic acid, which, being highly volatile, is entirely dissipated by exposure to heat at comparatively low temperatures, and the juice rendered innocuous. The solid residue from which the juice has been expressed, is harmless, and is available for making *cassava meal*, and when baked on hot plates, *cassava bread*.

The tubers of the sweet variety, when boiled or roasted, are used as an article of food.

Tapioca is the form in which cassava starch is chiefly used in this country as a food. It is partly soluble in cold water, owing to a portion of the starch granules having been ruptured by the heat in the process of preparation.

History.—In Brazil and other parts of South America, cassava meal or tapioca has contributed from the earliest date to the general food of the inhabitants. In 1625, Gage, in an account of his travels in Mexico, refers to the cassava tree, and to the varied uses of its alimentary products by the people. Humboldt, later on, during his travels in South America, found the tree in constant cultivation, and observed, that in some parts, cassava bread formed the staple food of the people.

We have been unable to find any record of the time when tapioca was first introduced into this country.

CHEMICAL COMPOSITION.

Both tapioca and tapioca flour practically consist of starch and water. The analyses of two commercial samples gave the following results:

	Tapioca. 1st quality.	Tapioca. 2nd quality.
Starch	85·02	86·39
Water	14·94	12·75
Albumin and impurities .	—	·80
Mineral matter . . .	·04	·06
Total .	100·00	100·00

MICROSCOPIC APPEARANCE.

The appearance of cassava starch as seen under the microscope is shown in Fig. 28 below:

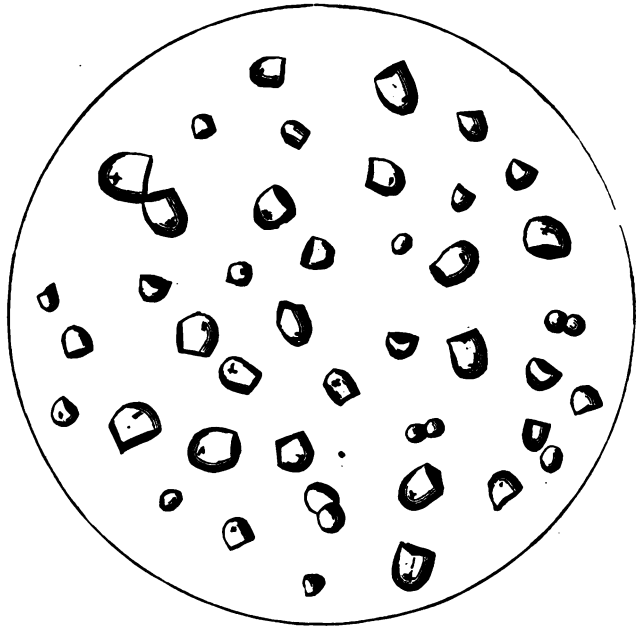

FIG. 28.—CASSAVA STARCH. MAGNIFIED 350 DIAMETERS.

The granules are round at one end, and have one or more straight faces. The hilum is distinct, and is situated near the round end of the granule. In size they vary from ·0003 to ·001 of an inch in length, and from ·0003 to ·0008 in breadth.

ADULTERATION.

There are cases recorded of tapioca flour or Brazilian arrow-root having been found adulterated with other starches of low commercial value, but in recent years such cases have been very rare. We have, however, lately met with a sample of pearl tapioca which consisted entirely of potato starch.

There are several starches, such as those of sago, rice, and potato, which, on account of their comparatively low price, could be profitably employed as adulterants of tapioca flour or a preparation of the same. With the aid of the microscope these starches can be recognised, and their presence established. The microscopic appearance of sago starch will be seen on page 166, Fig. 27; that of rice starch on page 121, Fig. 14; and that of potato starch on page 159, Fig. 22. Tapioca, as previously indicated, consists of a mixture of ruptured and unruptured starch granules, but the proportion of entire granules present is generally sufficient for the recognition of the character of the starch employed in the preparation of the article.

CORN FLOUR.

Corn flour usually consists of a preparation of the purified starch of maize (*Zea Mays*), or of rice (*Oryza sativa*).

From the name given to this article it might be supposed that it is the flour of the cereal in the same sense that wheat flour is of wheat; this, however, is not the case, as in the manufacture of corn flour almost the entire flesh and bone-forming constituents contained in the cereal are extracted, mainly by the action of soda, and the resulting product is composed of nearly a pure starch.

The following table contains the results of a proximate analysis of two samples of commercial corn flour prepared from maize and rice respectively:

TABLE I.—ANALYSES OF CORN FLOURS.

	Oswego (Maize) Corn Flour.	British (Rice) Corn Flour.
Starch	86·78	84·59
Nitrogenous matter ...	2·15	2·11
Mineral	·51	·33
Moisture	10·56	12·97
Total	100·00	100·00

If the constituents of maize and rice in Table I., page 86, are taken for comparison with the results given above, it will be seen that the nitrogenous matter is reduced from 15·27 to 2·15 per cent. in one case, and from 9.34 to 2·11 per cent. in the other; while the percentages of starch are increased from

64·66 to 86·78, and from 77·66 to 84·59 respectively, thus showing that the alimentary character of the original cereal is greatly altered in the corn flour. The latter, in fact, is essentially a starchy preparation, and as such should always be used in conjunction with milk or some other food rich in flesh and bone-forming substances.

The following is the result of the analysis of the ash of Oswego corn flour:

TABLE II.—ANALYSIS OF THE ASH OF CORN FLOUR.

Constituents.		
Potash	estimated as	K_2O 2·21
Soda	,,	Na_2O 20·07
Sodium Chloride ...	,,	NaCl 1·36
Magnesia	,,	MgO 5·71
Lime	,,	CaO 30·22
Iron Protoxide	,,	FeO ·51
Sulphuric Anhydride ...	,,	SO_3 2·28
Phosphoric ,, ...	,,	P_2O_5 1·42
Carbonic ,, ...	,,	CO_2 35·15
Silica	,,	SiO_2 1·07
Total		100·00

The proportion of phosphoric anhydride in the above sample is only 1·42 per cent. compared with 47·45 in the maize, as will be seen by Table II., page 88, and the amount of potash is reduced from 26·01 to 2·21 per cent.

The most notable feature about the ash of the corn flour is the large increase in the percentages of soda and lime, arising probably from contamination during the process of preparation.

The microscopic appearance of maize starch is represented in Fig. 29:

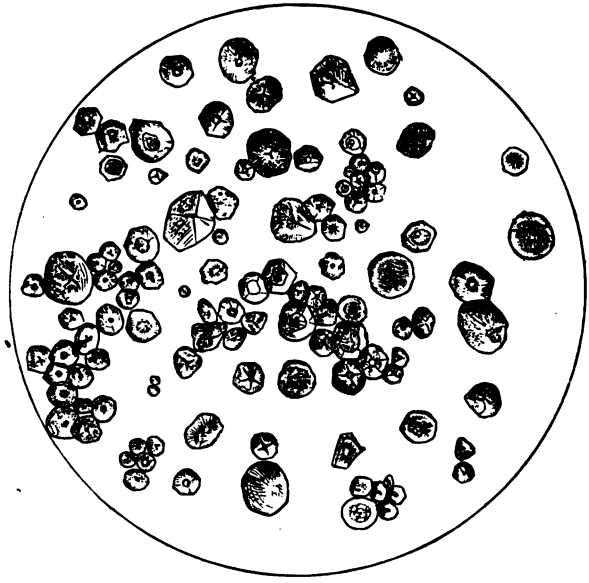

FIG. 29.—MAIZE STARCH. MAGNIFIED 350 DIAMETERS.

The granules are polygonal, and approaching the circular in shape. In size and general appearance they are intermediate between the starches of wheat and oats. They range in size from ·0002 to ·0012 inch in diameter.

Rice starch as seen under the microscope is shown in Fig. 14, page 121.

LENTIL FLOUR.

Origin.—Lentil flour is prepared from the seeds of the lentil plant, *Ervum lens*, belonging to the natural order *Leguminosæ*. The lentil is a native of Egypt, Palestine, Arabia, and other Eastern countries, where it has always formed a common and much-esteemed article of food. It is now also extensively grown in Italy and other countries bordering on the Mediterranean and in Germany.

Description.—The fruit consists of short, smooth, two-seeded pods, and, as met with in commerce, the seeds are about half the size of an ordinary pea, and of different colours, white, reddish-brown, or black, according to the variety of the plant cultivated. In the split state they are used in soups, and in that of flour in the form of gruel or porridge. The flour forms the basis of several proprietary preparations sold at high prices for the relief of certain disorders and as specially nutritive farinaceous foods. These preparations generally contain either wheat flour, barley meal, or Indian corn flour, with a little salt or sugar. The presence of these ingredients serves to modify the strong, and to some, objectionable flavour which lentils possess in common with other seeds of the *Leguminosæ*.

CHEMICAL COMPOSITION.

Lentil flour contains the following substances: fat, starch, sugar, albumin, cellulose, mineral matter, and water.

The following table contains the results of a proximate analysis of lentil flour:

TABLE I.—ANALYSIS OF LENTIL FLOUR.

Fat	1·10
Starch	50·47
Sugar	3·52
Albumin, soluble in alcohol ...	4·68
,, insoluble ,, ...	24·86
Cellulose	·92
Mineral matter	2·53
Moisture	11·92
Total	100·00

According to these results the proportion of starch in lentil flour is less than that found in the meal and flour of the cereals; but the amount of nitrogenous matter in the former is about double that which occurs in the latter. Lentil flour is therefore highly nutritious, and would, doubtless, be much more extensively used were it not for its strong taste and flavour.

The following table contains the results of the analysis of the ash of split lentils:

TABLE II.—ANALYSIS OF THE ASH OF SPLIT LENTILS.

Constituents.		
Total Ash on Dry Lentils ...	Per cent.	2·87
Potash	estimated as K_2O	32·60
Potassium Chloride ...	,, KCl	8·28
Sodium Chloride	,, NaCl	4·65
Magnesia	,, MgO	5·67
Lime	,, CaO	2·05
Oxide of Iron	,, FeO	1·81
Alumina	,, Al_2O_3	0·28
Oxide of Manganese ...	,, Mn_3O_4	Traces.
Sulphuric Anhydride ...	,, SO_3	Traces.
Phosphoric Anhydride ...	,, P_2O_5	38·33
Silica	,, SiO_2	3·63
Sand		2·70
Total		100·00

ANALYSIS.

The methods for the determination of the constituents of lentil flour are the same as those adopted in the analysis of flour described on pages 105 to 109.

MICROSCOPIC STRUCTURE.

The starch granules of lentil flour are similar in form and appearance to those of the pea and bean exhibited in Figs. 15 and 16, pages 122 and 123. The concentric rings, however, of the former are more distinct, and the longitudinal depression more clearly defined than in the latter.

ADULTERATION.

Lentil flour being as cheap if not cheaper than other farinaceous substances, it is seldom if ever adulterated. The presence of cereal, and most other foreign starches, if mixed with lentil flour, can be detected by the microscope.

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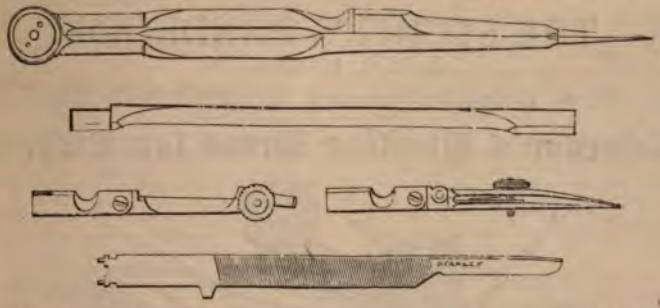

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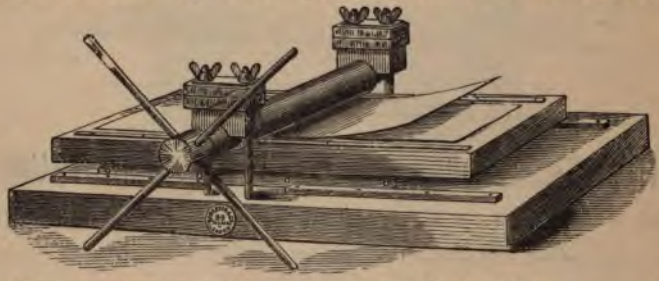

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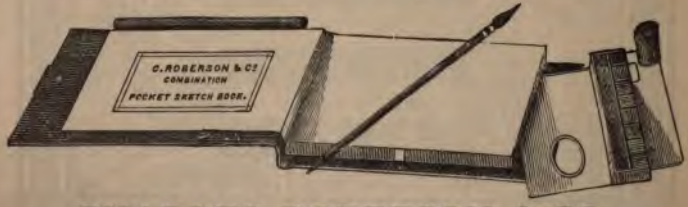

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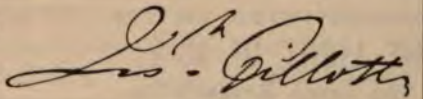

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